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CMCiB Comparative Medicine & Bioimage Centre of Catalonia
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Daily report 29-04-2020

Analysis and prediction of COVID-19 for EU-EFTA-UK and other countries

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Foreword

The present report aims to provide a comprehensive picture of the **pandemic situation of COVID-19** in the EU countries, and to be able to foresee the situation in the next coming days.

We employ an **empirical model**, verified with the evolution of the number of confirmed cases in previous countries where the epidemic is close to conclude, including all provinces of China. The model does not pretend to interpret the causes of the evolution of the cases but to permit the **evaluation of the quality of control measures made in each state** and a **short-term prediction of trends**. Note, however, that the effects of the measures' control that start on a given day are not observed until approximately 7-10 days later.

The model and predictions are based on two parameters that are daily fitted to available data:

- ✓ *a*: the velocity at which spreading specific rate slows down; the higher the value, the better the control.
- ✓ *K*: the final number of expected cumulated cases, which cannot be evaluated at the initial stages because growth is still exponential.

We show an individual report with 8 graphs and a table with the **short-term predictions** for different countries and regions. We are adjusting the model to **countries and regions** with at least 4 days with more than 100 confirmed cases and a current load over 200 cases. The **predicted period** of a country depends on the number of datapoints over this 100 cases threshold, and is of 5 days for those that have reported more than 100 cumulated cases for 10 consecutive days or more. For short-term predictions, we assign higher weight to last 3 points in the fittings, so that changes are rapidly captured by the model. The whole methodology employed in the inform is explained in the last pages of this document.

In addition to the individual reports, the reader will find an initial dashboard with a brief analysis of the situation in EU-EFTA-UK countries, some summary figures and tables as well as **long-term predictions** for some of them, when possible. These long-term predictions are evaluated without different weights to data-points. We also discuss a specific issue every day.

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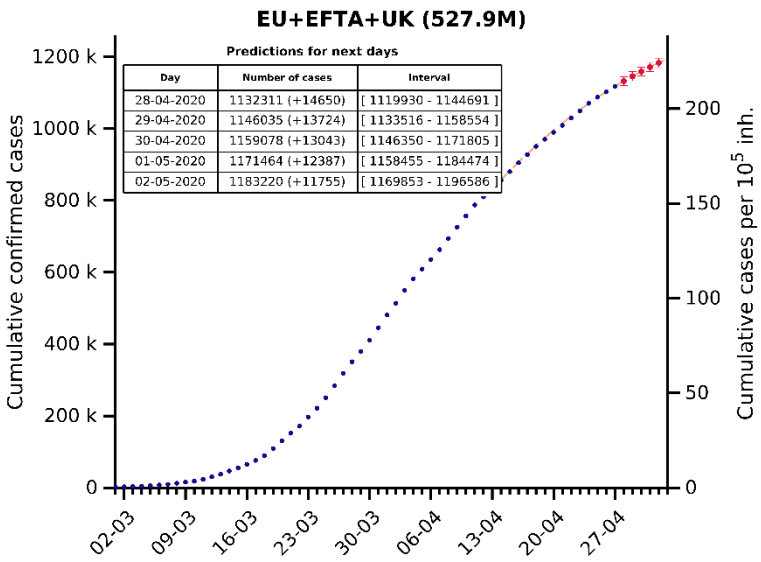
(0) Executive summary – Dashboard

Global EU+EFTA+UK trends and needs

EU+EFTA+UK countries have, individually, a **daily number of cases per 100,000 inhabitants lower than 5**, clearly showing that we are already consolidating the decline. It should be noted that in some countries such as Spain, Belgium, Ireland, Luxembourg or Iceland, values of 20 or more had been reached at some point. In all countries the value is of the order of only 2 new cases per 100,000 inhabitants. The reason is that there are many states where the epidemic has not grown significantly at any time. The decline is consolidating, but it should be kept in mind that this decrease is not due to the limitation on the number of susceptible people but to the control measures that hinder the transmission of the virus. **Many countries are currently planning or implementing deconfinement measures**. Thus, we need to be careful, **if a good epidemiological surveillance system is not established the number of cases can grow disproportionately**.



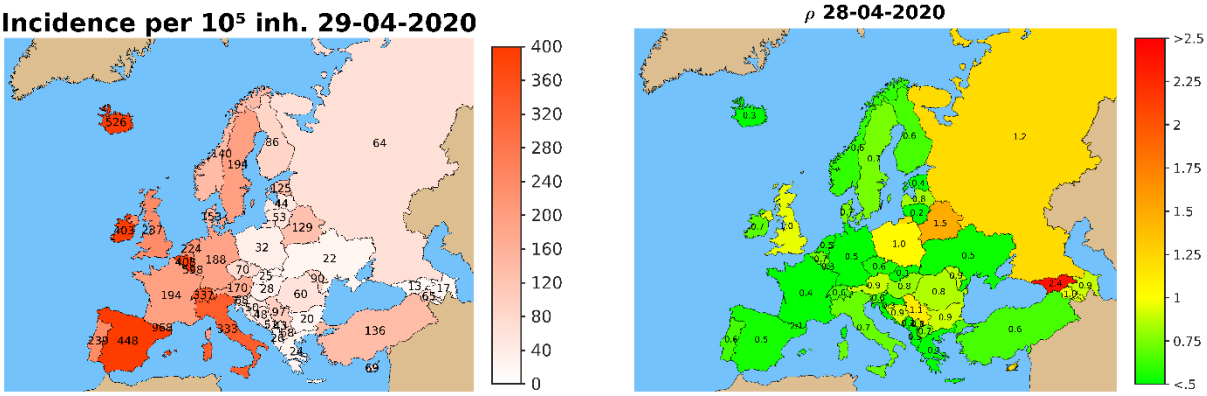
Another of the parameters that shows that we are in the decline phase is the number of daily deaths. At certain times we had reached values of 5,000 deaths in one day, while we are now at only 30% of this maximum value, as the number of daily deaths is of the order of 1,500.

Trends for specific countries

4 countries present a situation that requires attention. They are those countries where the attack rate of the last 14 days is really high, especially if we look at its estimated value: **Belgium** (about 2,600 per 10^5 inhabitants), **Ireland** (around 2,400) and **UK** and **Sweden** (around 1,400).

One country that deserves attention is **Iceland**, not because it is in danger, but the opposite. Iceland had been reached more than 25 daily new cases per 100,000 inhabitants, with a ρ around 2. Nevertheless, it is now among the countries that are best controlling the epidemic. In the last few days they have less than 5 cases a day (in absolute numbers) and a ρ_7 of 0.3. It is certainly a very small country, and this makes the speed at which an epidemic can be controlled to be high but, in any case, they are the proof that control is possible. A CFR at the order of 0.6 also shows that they have done an excellent job.

The map in the right shows the current ρ, therefore, without the smoothing provided by the 7-day moving average.



Situation and trends per country

Table of current situation in EU countries. Colour scale is relative except when indicated, this means that it is applied independently to each column, and distinguishes best (green) form worst (red) situations according to each of the variables. **New!** Last column (**EPG_{EST}**) indicates EPG assessed with **estimated real 14-day attack rate** (see report 39 for details). **EPG_{REP}** is calculated with **data reported by countries**. EPG_{REP} and EPG_{EST} **cannot be compared between them** because scales are different, but can be independently used for estimating risk of countries according to reported or estimated real situation, respectively.

	Reported data						Indexes		
Country	Cumulative cases	Attack rate /10^5 inh.	Cumulative deaths	Mortality /10^5 inh.	Active cases (last 14 days)	14-day attack rate /10^5 inh.	ρ_7 [1]	EPG_{REP} [2]	EPG_{EST} [3]
Spain	210,773	454.8	23,822	51.4	38,809	83.7	0.84	70	806
Italy	201,505	339.1	27,359	46.0	39,017	65.7	0.84	55	772
United Kingdom	161,145	242.5	21,678	32.6	67,272	101.3	0.93	94	1,395
Germany	157,641	192.4	6,115	7.5	30,057	36.7	0.74	27	121
France	126,835	196.0	23,660	36.6	23,262	35.9	0.88	32	669
Belgium	47,334	416.7	7,331	64.5	16,215	142.8	0.79	113	1,976
Netherlands	38,416	226.1	4,566	26.9	10,997	64.7	0.72	47	579
Switzerland	29,181	340.5	1,379	16.1	3,428	40.0	0.68	27	132
Portugal	24,322	234.5	948	9.1	6,874	66.3	0.87	58	245
Ireland	19,877	420.6	1,159	24.5	8,398	177.7	0.95	169	1,229
Sweden	19,621	199.4	2,355	23.9	8,176	83.1	1.06	88	1,600
Austria	15,314	175.8	569	6.5	1,080	12.4	0.90	11	43
Poland	12,218	32.0	596	1.6	5,016	13.1	0.91	12	75
Romania	11,616	58.7	650	3.3	4,737	24.0	0.99	24	156
Denmark	8,851	155.0	434	7.6	2,340	41.0	0.99	40	215
Norway	7,605	141.7	195	3.6	1,039	19.4	0.75	15	39
Czech Republic	7,504	70.7	227	2.1	1,363	12.8	0.64	8	27
Finland	4,740	86.1	199	3.6	1,579	28.7	0.89	25	133
Luxembourg	3,741	649.5	89	15.5	434	75.3	0.58	43	ND
Hungary	2,727	28.0	300	3.1	1,148	11.8	0.94	11	167
Greece	2,534	22.7	136	1.2	364	3.3	3.65	12	72
Croatia	2,047	48.6	63	1.5	343	8.1	0.77	6	ND
Iceland	1,795	492.8	10	2.7	75	20.6	0.31	6	ND
Estonia	1,660	126.5	50	3.8	287	21.9	0.79	17	ND
Lithuania	1,449	49.8	44	1.5	379	13.0	0.37	5	ND
Slovenia	1,408	67.8	86	4.1	188	9.0	0.90	8	ND
Bulgaria	1,399	19.6	58	0.8	686	9.6	1.61	15	ND
Slovakia	1,384	25.4	20	0.4	549	10.1	0.54	5	ND
Cyprus	837	71.5	20	1.7	142	12.1	0.74	9	ND
Latvia	836	42.4	13	0.7	179	9.1	0.92	8	ND
Malta	450	104.9	4	0.9	57	13.3	ND	ND	ND
Liechtenstein	83	215.3	1	2.6	2	5.2	ND	ND	ND
	Scale								
	Worst	Worst	Worst	Worst	Worst	Worst	2.0	500	2500
	Best	Best	Best	Best	Best	Best	0.0	0	0

[1] ρ_3 is the average of 7 consecutive ρ, but can still fluctuate. [2] EPG stands for Effective Growth Potential. EPG_{REP} is obtained by multiplying attack rate of last 14 days per 10^5 inhabitants (i.e. density of cases) by ρ_3 (a value related with effective reproduction number and that, therefore, determines the dynamics for subsequent days). EPG_{EST} is obtained by multiplying estimated real attack rate of last 14 days per 10^5 inhabitants by ρ_3.

Highlights for countries with highest number of reported cases

- ✓ France, with 23,293 reported deaths, has overtaken Spain (23,190 reported deaths). However, they are still far from Italy, with 26,977. UK, with 21,092 deaths, is also one of the countries with the highest values in number of deaths.
- ✓ The positive part is the whole group of countries with the highest number of reported cases have ρ_7 lower than 1 (Germany 0.7; Spain, Italy and Belgium 0.8; France and UK 0.7).

Time indicators by country

This table summarizes a few time indicators for each country: time since 50 cases were reported, time interval between an attack rate of $1/10^5$ inhabitants and an attack rate of $10/10^5$ inhabitants, and time interval between attack rates of 10 to 100 per 10^5 inhabitants (only for countries that have overtaken this threshold).

Countries	Days since the first 50 cases	Time interval between 1 and 10 cases / 10^5 inh. (days)	Time interval between 10 and 100 cases / 10^5 inh. (days)
Italy	67	11	16
France	61	10	20
Germany	61	12	17
Spain	59	7	12
United Kingdom	57	11	19
Norway	56	9	24
Switzerland	56	9	12
Netherlands	55	11	20
Sweden	55	10	28
Austria	54	10	14
Belgium	54	11	14
Greece	53	18	ND
Iceland	53	5	15
Denmark	51	4	30
Czech Republic	50	11	ND
Finland	49	12	ND
Portugal	49	9	15
Slovenia	49	6	ND
Ireland	48	8	18
Romania	48	15	ND
Estonia	47	5	30
Poland	47	16	ND
Bulgaria	45	19	ND
Luxembourg	45	6	7
Slovakia	45	21	ND
Croatia	44	12	ND
Latvia	43	12	ND
Cyprus	42	12	ND
Hungary	42	16	ND
Malta	41	8	34
Lithuania	40	9	ND
Liechtenstein	35	9	11

Analysis: Can we predict the effect of an increase in mobility due to deconfinement?

The spreading of COVID-19 all over the world has forced the countries to develop strong mobility protocols to increase social distancing. These strong measures, in combination with massive testing programs, are the main tools for blocking COVID-19 propagation. The variability of these protocols through different countries is still a matter of discussion. **A very important concern in European countries, now, is how the relaxation of measures will affect the dynamics of the epidemic.** Can we forecast the evolution of incidence, given the plans of the governments to raise restrictions, if we can follow basic aggregate mobility data?

We propose that the most reasonable way to quantitatively assess this possibility is to use empirical models. As we have said in other assessments, the key pathways of contagion are not clear. In blunt terms, we do not know if people get infected mainly in elevators and public transport or by short physical presence due to the direct emission of droplets. It is known that both are probable pathways of contagion but it is not clear which path is more relevant. This renders quantitative multivariable models that need to be calibrated in worse footing than purely empirical approaches.

In the previous assessments we have evaluated the evolution of the pandemic in terms of the spreading rate ρ. It is evaluated as follows:

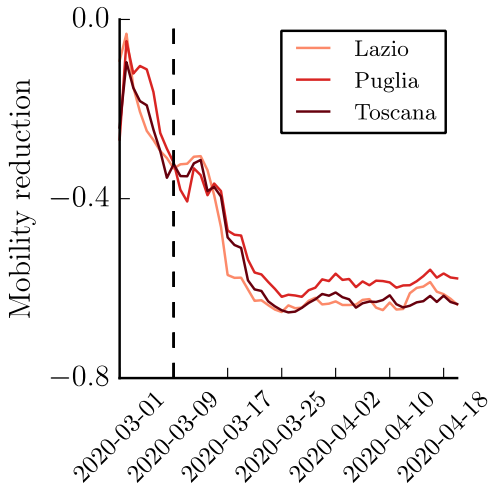
$$\rho(t-1) = \frac{N(t) + N(t-1) + N(t-2)}{N(t-5) + N(t-6) + N(t-7)}$$

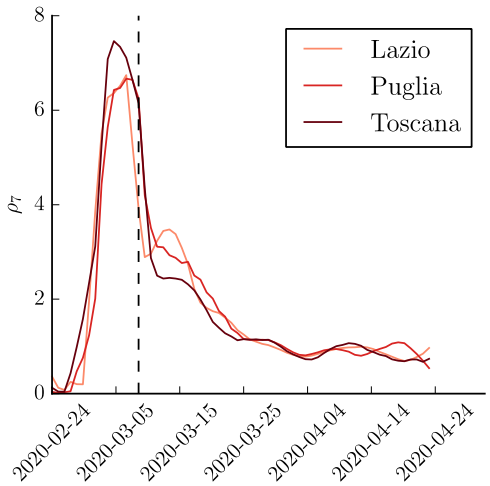
This variable is related with the reproduction number, i.e., with the number of new infections caused by a single case. Values of ρ below 1 mean that the number of new is slowing down, while ρ above 1 means that the number of new cases is increasing. Thus, knowing the time series of ρ and the initial new cases, one could recover the evolution of the pandemic:

$$\bar{N}(t-1) = \frac{1}{3}\rho(t-1)[N(t-5) + N(t-6) + N(t-7)]$$

where we assume that the new cases at time t are given by the mean value $\bar{N}(t)$. Then**, if one has an empirical estimation of ρ, it is possible to calculate the new cases.** To address this issue, we have related ρ with the mobility reduction using experimental data.

In the figure below, we show the mobility reduction in three regions of Italy. The dashed line indicates the first curfew declared in this country (9th March). The social distancing in Italy was imposed gradually during the first two weeks of March. In the second figure (right) we show the evolution of ρ_7 during the pandemic.

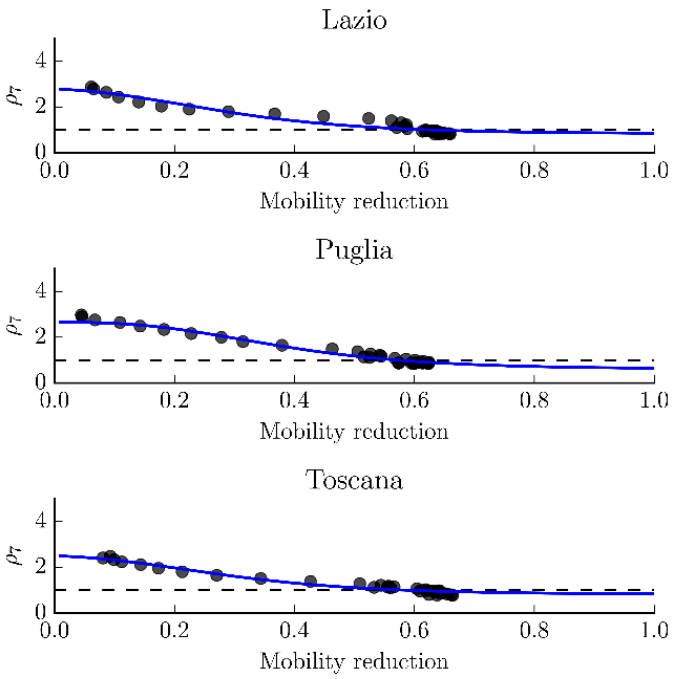




Thus, we have obtained the **experimental relation between both magnitudes**. In order to reduce the so-called "weekend effect", we have smoothed both signals by applying a 7-day moving average. In the following figure we show the scatter plot (black dots) and the fitting with a modified version of the Gompertz function (blue line). It reads as:

$$\rho(\mu) = \rho_o + K - G(\mu; K, a, N_o, \mu_o)$$

where $G(\mu)$ is the Gompertz function. Both variables have been displaced 10 days, because of the delay between curfew measures and the effect seen in spreading rate (see previous reports). This delay is estimated through the correlation time between mobility and ρ. Other functions are being tested to check if they are appropriate.

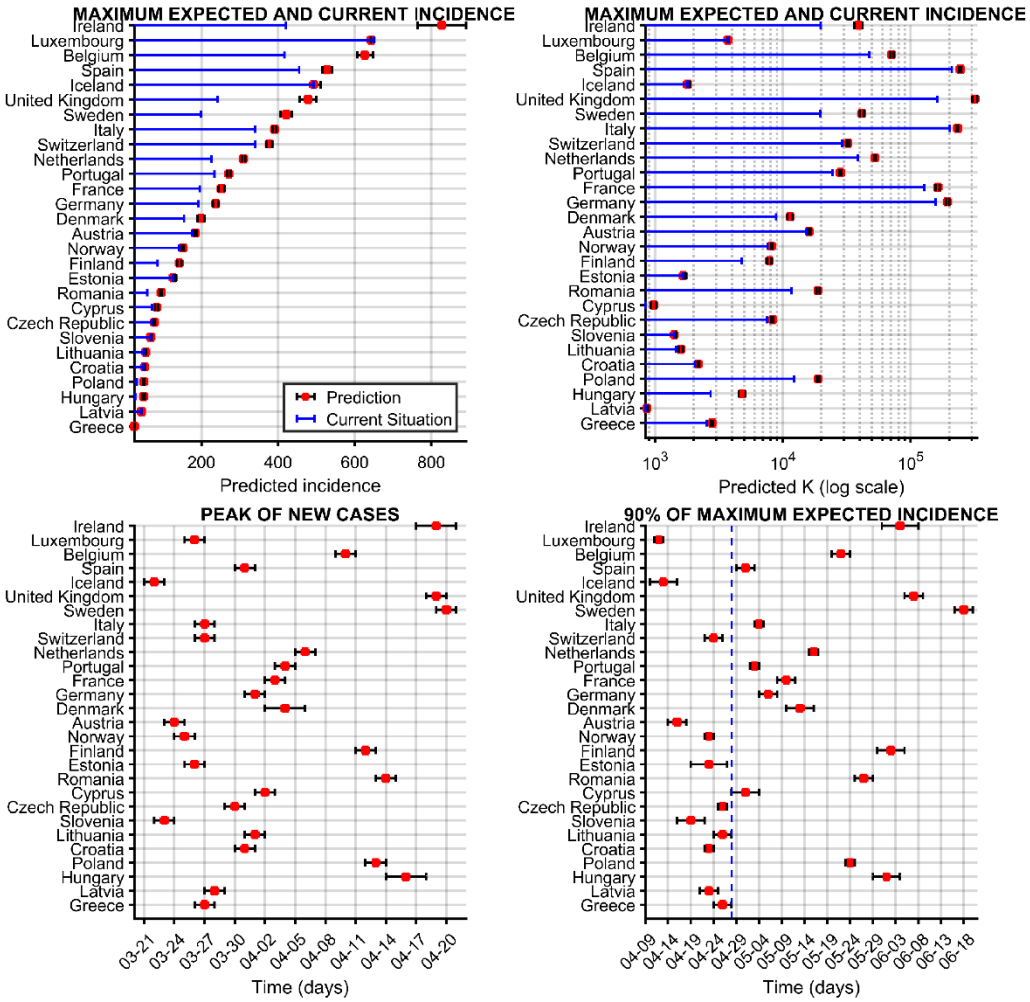


With this empirical relation, it is possible to predict the new cases as function of the mobility reduction as follows: if mobility is daily tracked, one could provide an estimation of ρ ten days later using the fitted function. Then, given the estimated $\rho(t)$, it is possible to provide an estimation for new cases ($\overline{N}(t)$).

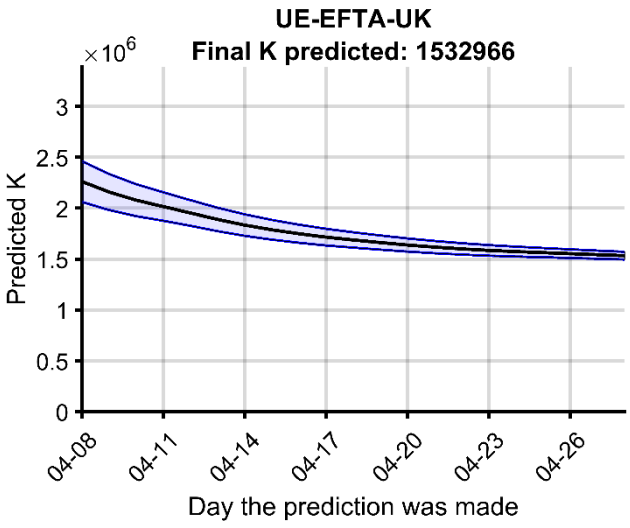
We should stress that this procedure provides only a worst-case scenario for the reopening process. The reason is that the reduction in mobility does not necessarily affect ρ in the same quantitative manner as we increase mobility than we decrease it, given the expected differences in social behavior. We expect that social interactions are now different from two months ago, due to citizen's awareness of the epidemic. Moreover, generalized use of masks, which is being recommended by governments, should prevent the recovery of original values protecting the contamination of surfaces in public places and in indoor gatherings. **This means that the same amount of mobility can lead to a much lower level of infections** Consider a simple example. Someone who has been at home most of the time during the previous weeks returns to work and meets some people in small gatherings. Its mobility might increase 3o points. Our back of the envelope calculation is that its ability to produce a contagion if he/she were infected would increase two-fold if the type of contact from hand-shaking, hugging, physical distance, contact with surfaces, cleaning of hands... has not changed at all. Obviously, the behavior will not be the same as before, so the increase in the ability to infect other people will be much lower. It is thus clear that **using the obtained estimations described above should be taken as an upper bound, or a worst-case scenario where nobody changes behavior despite previous confinement, that can be checked against updated data as the process unfolds.**

Long-term predictions

Long-term predictions, evaluated with the **whole historical series** and without weighting last 3 points. Up-left: Predictions of maximum incidences per country (total final expected attack rate per 10^5 inh.). Up-right: Predictions of maximum absolute number of cases per country (K, in log scale). Blue lines indicate current situation. Bottom-left: Time in which peak in new cases was achieved / will be achieved. Bottom-right: Time at which 90 % of K was achieved / will be achieved. Blue dotted line indicates current date.



Final expected K for UE+EFTA+UK. Evolution of predicted K with time, where convergence to best estimate is seen. Last prediction is numerically shown in title.



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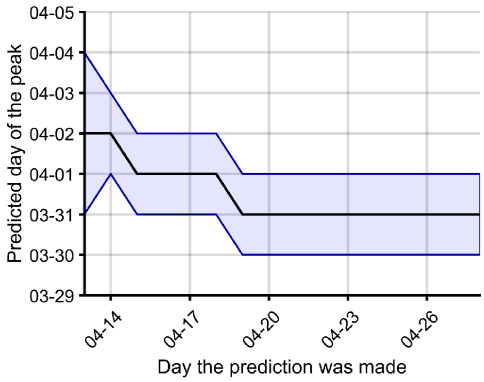
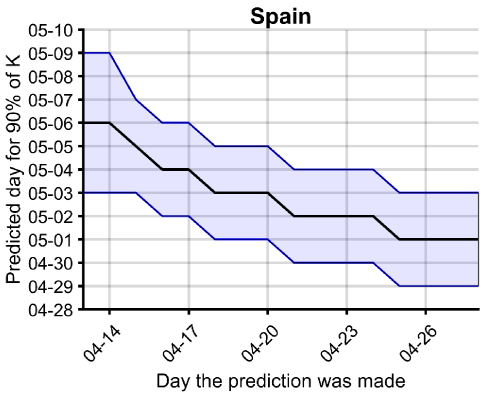
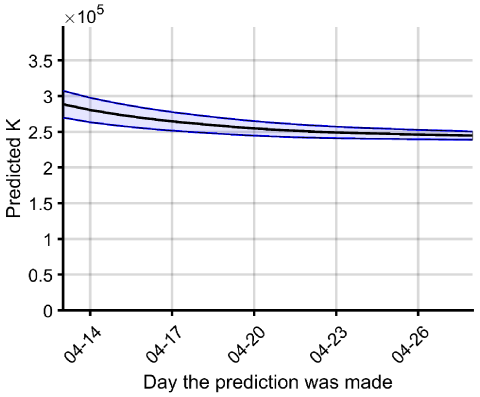
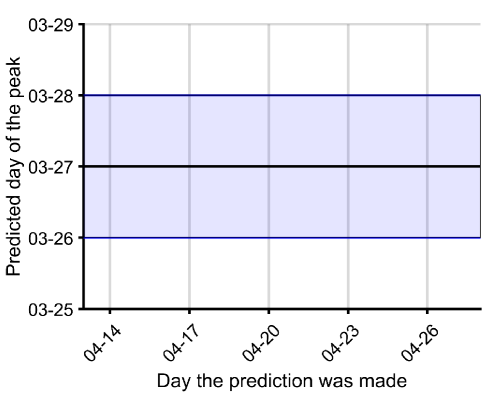
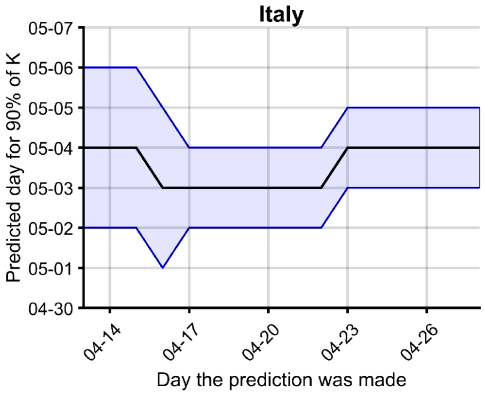
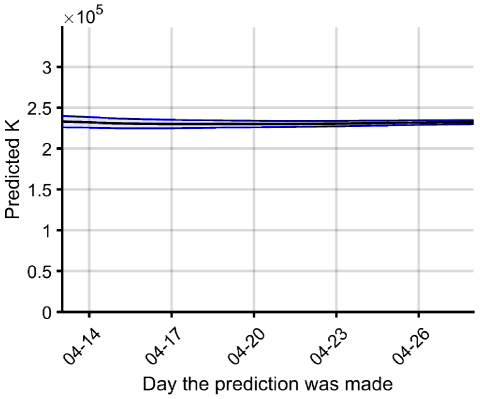

Predicted day of the peak
04-05
04-04
04-03
04-02
04-01
03-31
03-30
03-29
04-14
04-17
04-20
04-23
04-26
Day the prediction was made

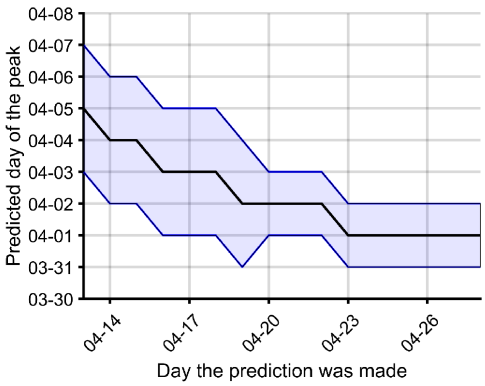

Spain
Predicted day for 90% of K
05-10
05-09
05-08
05-07
05-06
05-05
05-04
05-03
05-02
05-01
04-30
04-29
04-28
04-14
04-17
04-20
04-23
04-26
Day the prediction was made

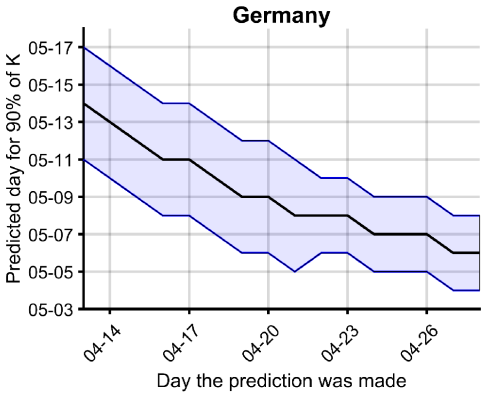

×10^5
Predicted K
3.5
3
2.5
2
1.5
1
0.5
0
04-14
04-17
04-20
04-23
04-26
Day the prediction was made

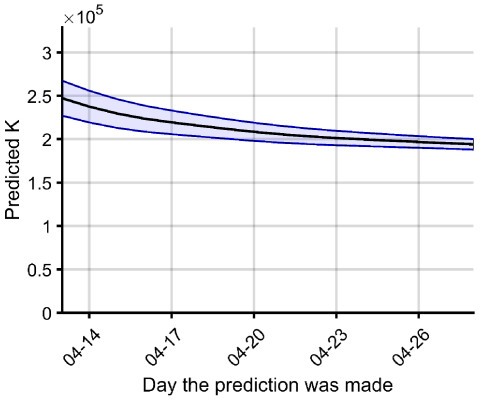

Predicted day of the peak
03-29
03-28
03-27
03-26
03-25
04-14
04-17
04-20
04-23
04-26
Day the prediction was made

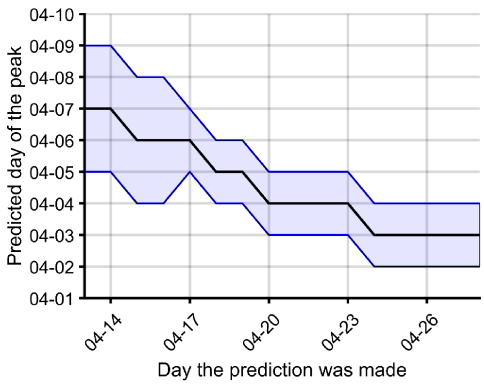

Italy
Predicted day for 90% of K
05-07
05-06
05-05
05-04
05-03
05-02
05-01
04-30
04-14
04-17
04-20
04-23
04-26
Day the prediction was made

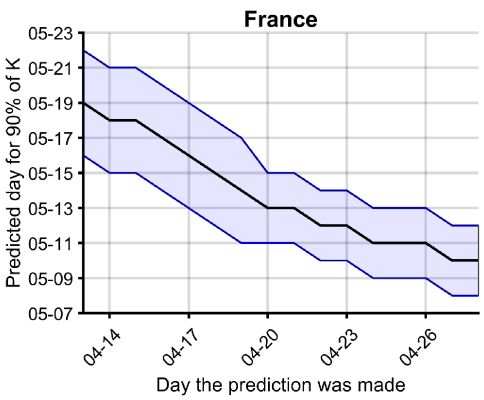

×10^5
Predicted K
3
2.5
2
1.5
1
0.5
0
04-14
04-17
04-20
04-23
04-26
Day the prediction was made

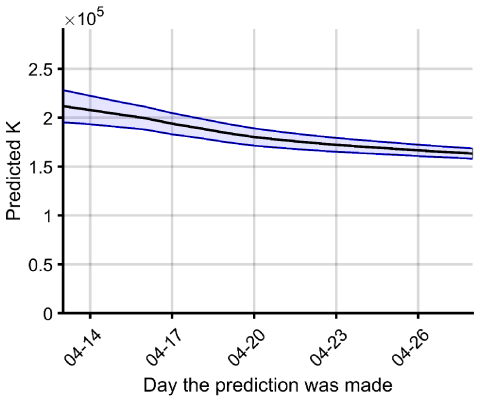

Predicted day of the peak
04-08
04-07
04-06
04-05
04-04
04-03
04-02
04-01
03-31
03-30
04-14
04-17
04-20
04-23
04-26
Day the prediction was made

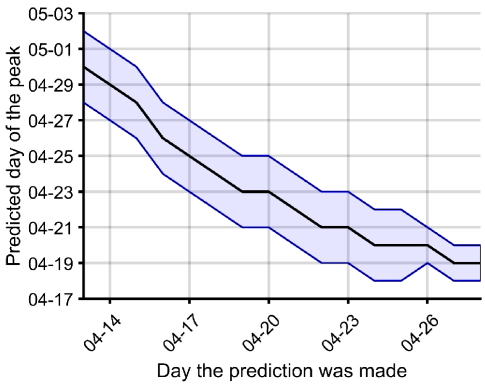

Germany
Predicted day for 90% of K
05-17
05-15
05-13
05-11
05-09
05-07
05-05
05-03
04-14
04-17
04-20
04-23
04-26
Day the prediction was made

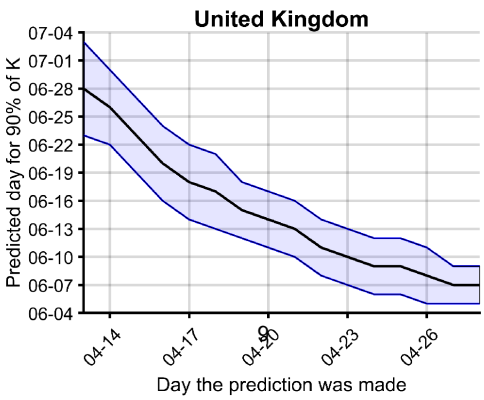

×10^5
Predicted K
3
2.5
2
1.5
1
0.5
0
04-14
04-17
04-20
04-23
04-26
Day the prediction was made

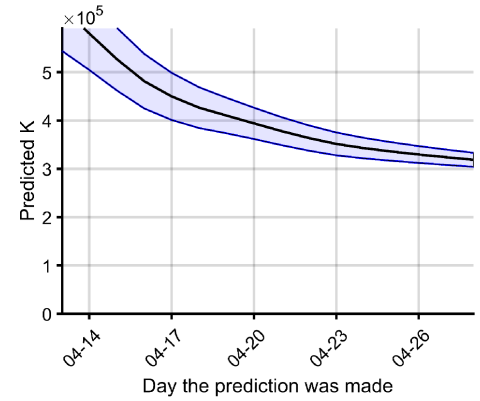

Predicted day of the peak
04-10
04-09
04-08
04-07
04-06
04-05
04-04
04-03
04-02
04-01
04-14
04-17
04-20
04-23
04-26
Day the prediction was made


France
Predicted day for 90% of K
05-23
05-21
05-19
05-17
05-15
05-13
05-11
05-09
05-07
04-14
04-17
04-20
04-23
04-26
Day the prediction was made

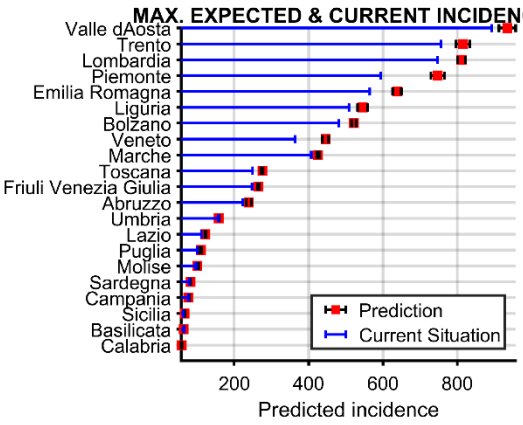

×10^5
Predicted K
2.5
2
1.5
1
0.5
0
04-14
04-17
04-20
04-23
04-26
Day the prediction was made

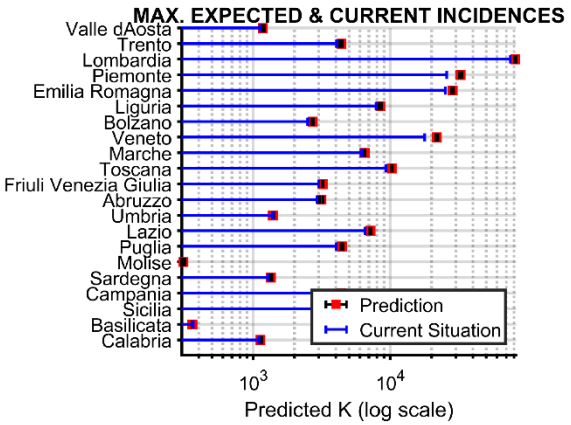

Predicted day of the peak
05-03
05-01
04-29
04-27
04-25
04-23
04-21
04-19
04-17
04-14
04-17
04-20
04-23
04-26
Day the prediction was made

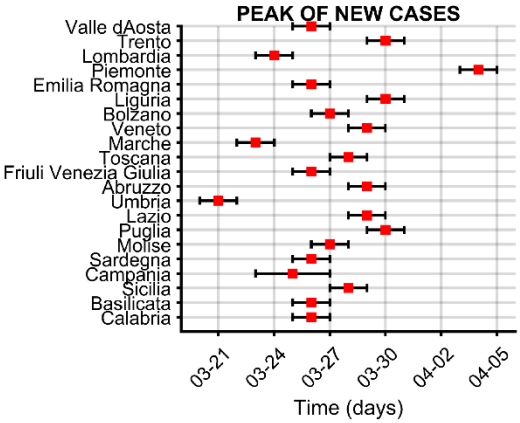

United Kingdom
Predicted day for 90% of K
07-04
07-01
06-28
06-25
06-22
06-19
06-16
06-13
06-10
06-07
06-04
04-14
04-17
04-20
04-23
04-26
Day the prediction was made

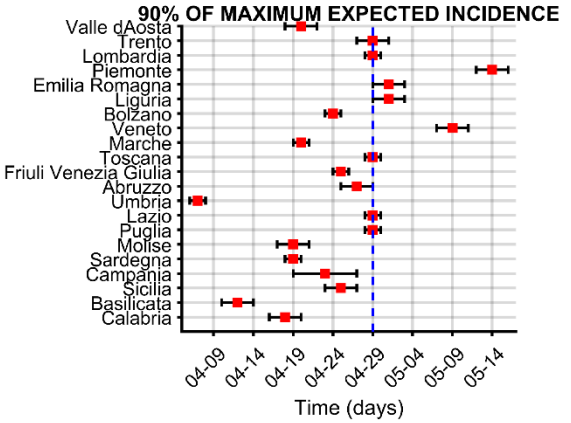

×10^5
Predicted K
5
4
3
2
1
0
04-14
04-17
04-20
04-23
04-26
Day the prediction was made

Italian regions

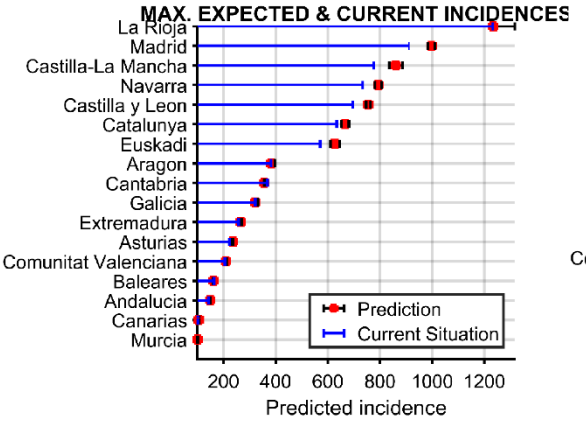


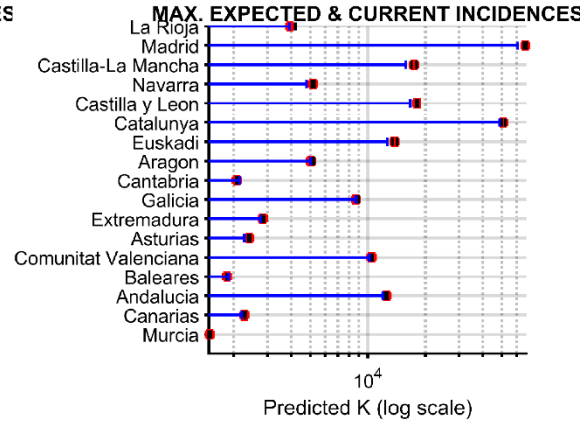


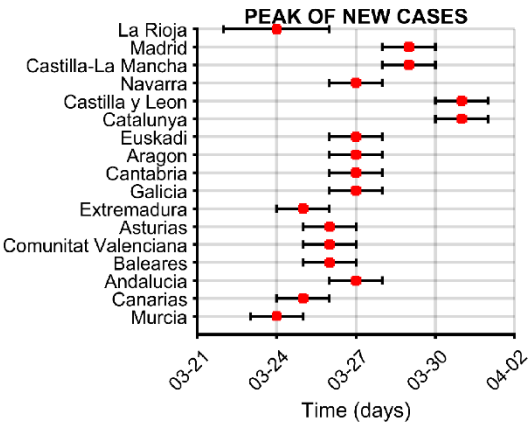


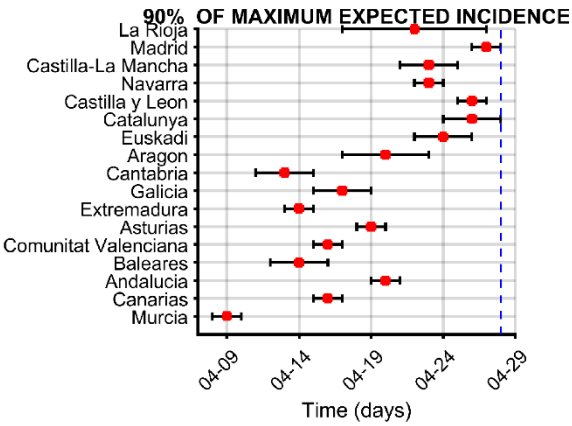


Spanish regions

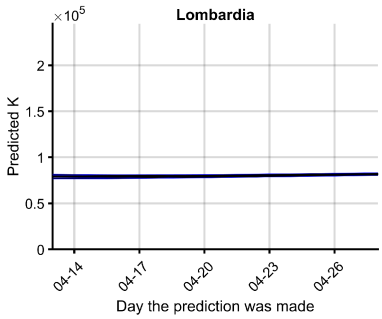


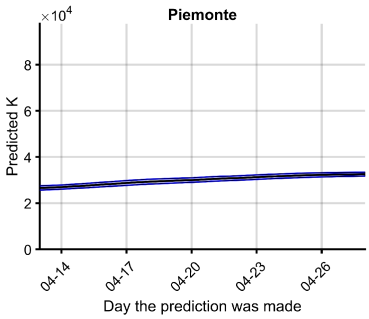


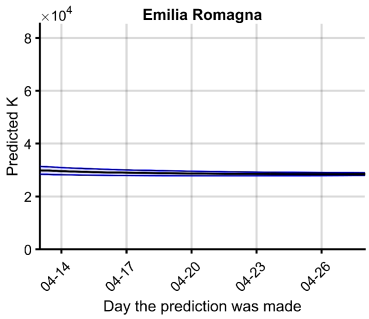


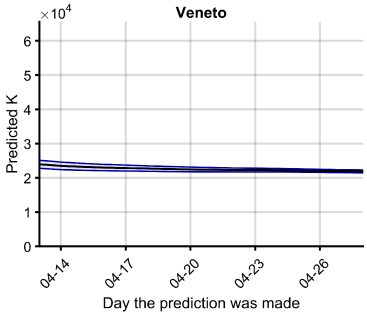


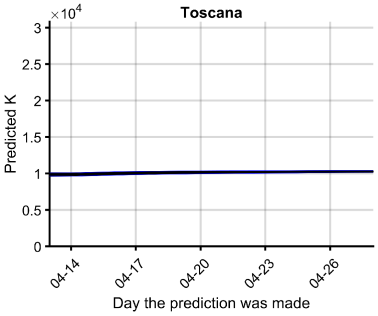
2020-04-29

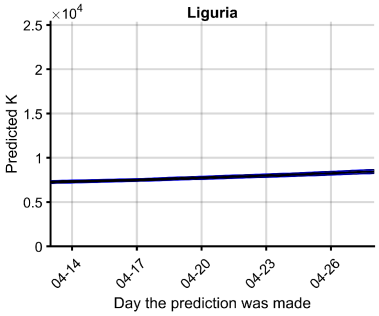

Lombardia
×10^5
Predicted K
Day the prediction was made

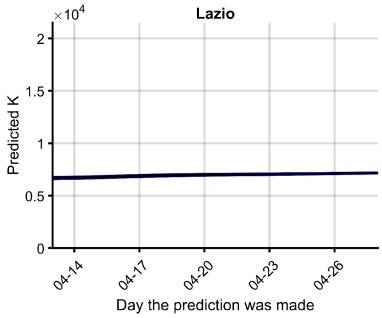

Piemonte
×10^4
Predicted K
Day the prediction was made

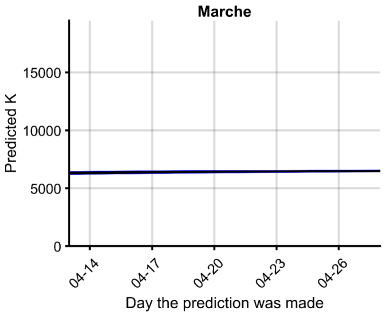

Emilia Romagna
×10^4
Predicted K
Day the prediction was made

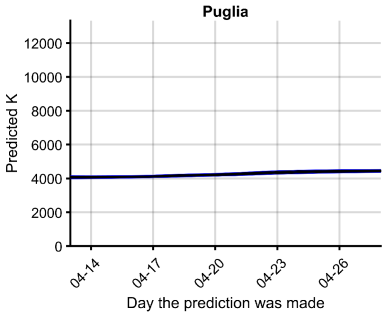

Veneto
×10^4
Predicted K
Day the prediction was made

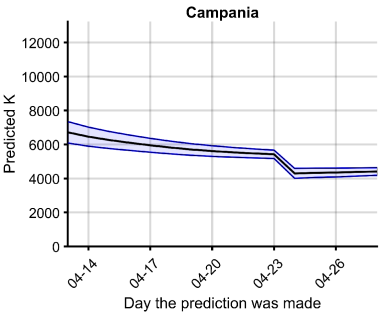

Toscana
×10^4
Predicted K
Day the prediction was made

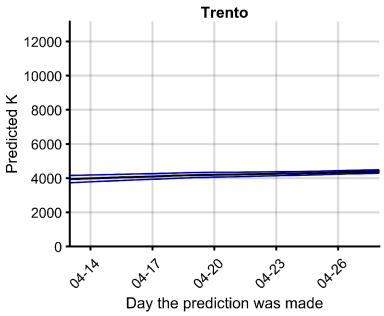

Liguria
×10^4
Predicted K
Day the prediction was made

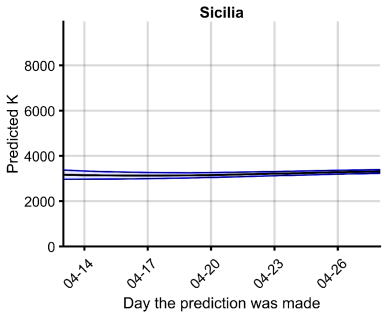

Lazio
×10^4
Predicted K
Day the prediction was made

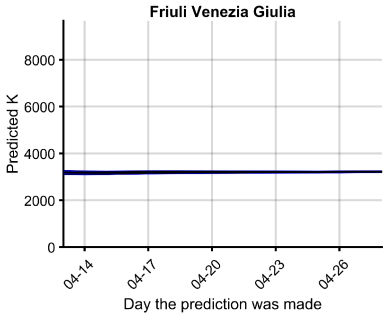

Marche
Predicted K
Day the prediction was made

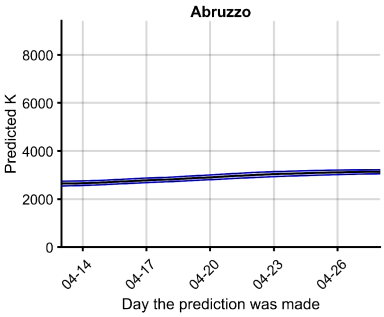

Puglia
Predicted K
Day the prediction was made

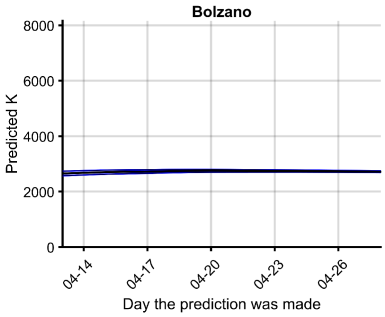

Campania
Predicted K
Day the prediction was made

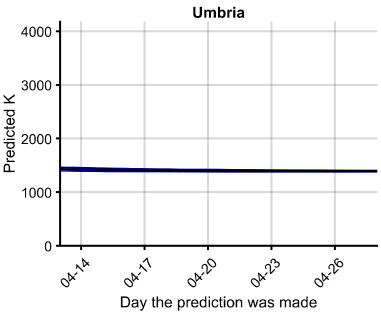

Trento
Predicted K
Day the prediction was made

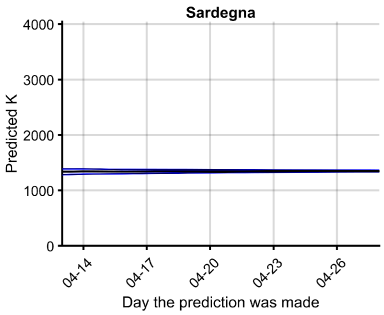

Sicilia
Predicted K
Day the prediction was made

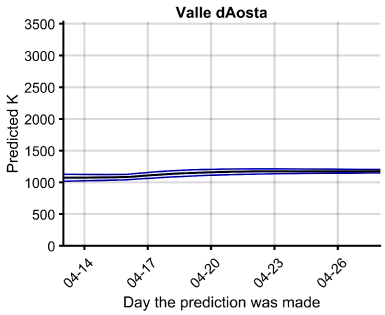

Friuli Venezia Giulia
Predicted K
Day the prediction was made

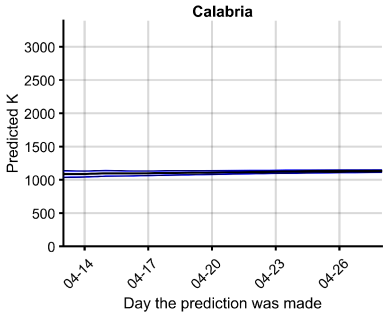

Abruzzo
Predicted K
Day the prediction was made

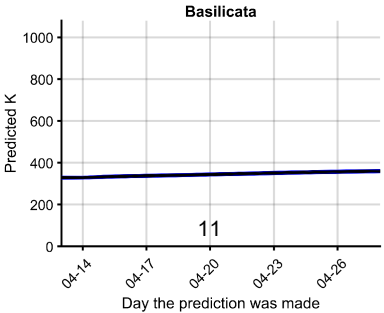

Bolzano
Predicted K
Day the prediction was made

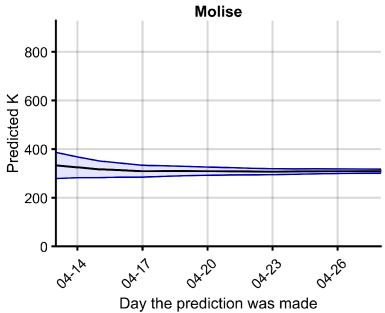

Umbria
Predicted K
Day the prediction was made


Sardegna
Predicted K
Day the prediction was made

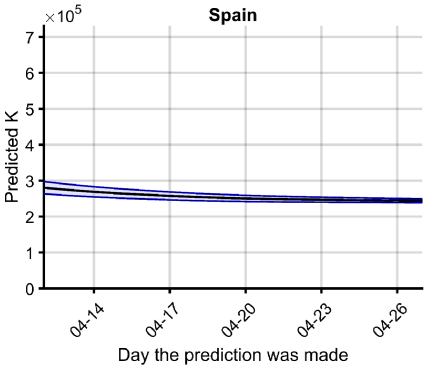

Valle dAosta
Predicted K
Day the prediction was made

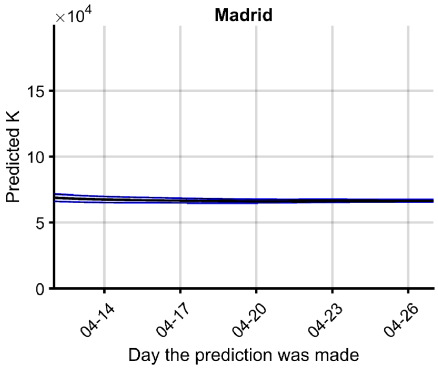

Calabria
Predicted K
Day the prediction was made

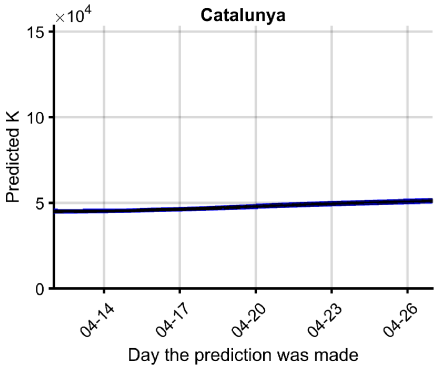

Basilicata
Predicted K
Day the prediction was made

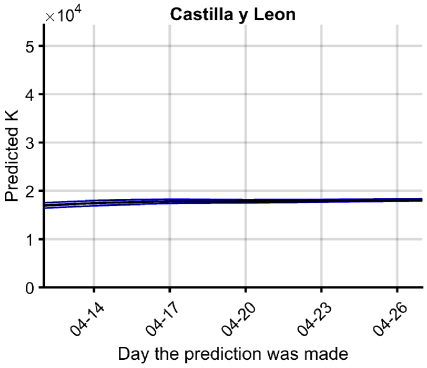

Molise
Predicted K
Day the prediction was made

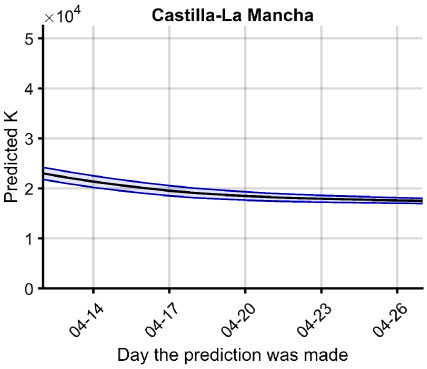
2020-04-28

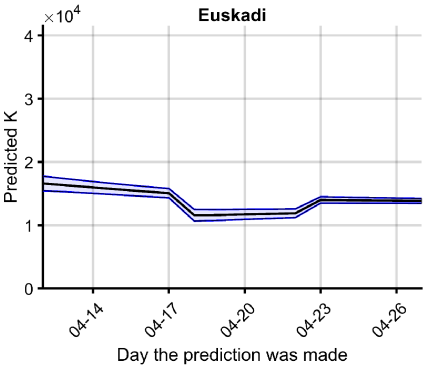

Spain
×10^5
Predicted K
Day the prediction was made
04-14
04-17
04-20
04-23
04-26

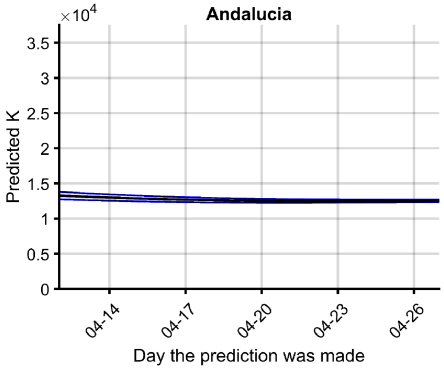

Madrid
×10^4
Predicted K
Day the prediction was made
04-14
04-17
04-20
04-23
04-26

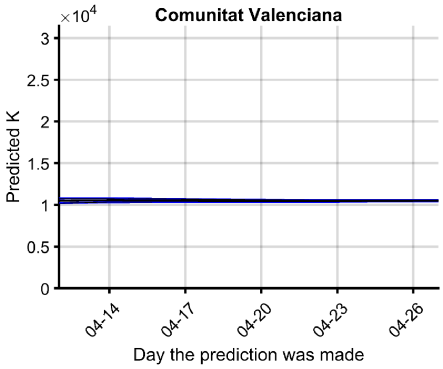

Catalunya
×10^4
Predicted K
Day the prediction was made
04-14
04-17
04-20
04-23
04-26

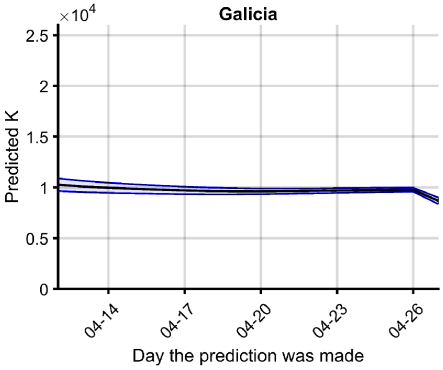

Castilla y Leon
×10^4
Predicted K
Day the prediction was made
04-14
04-17
04-20
04-23
04-26

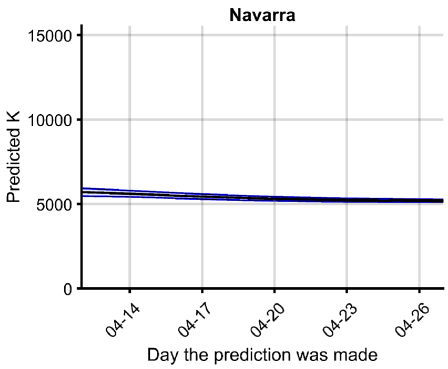

Castilla-La Mancha
×10^4
Predicted K
Day the prediction was made
04-14
04-17
04-20
04-23
04-26

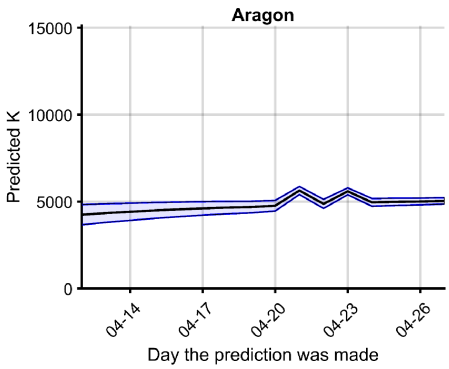

Euskadi
×10^4
Predicted K
Day the prediction was made
04-14
04-17
04-20
04-23
04-26

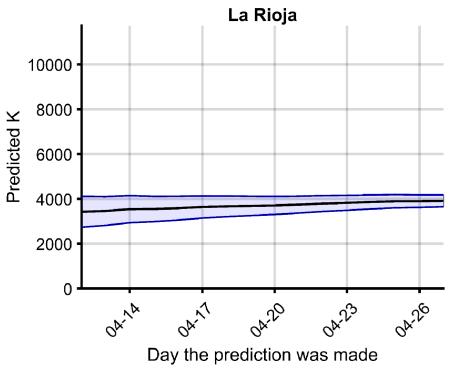

Andalucia
×10^4
Predicted K
Day the prediction was made
04-14
04-17
04-20
04-23
04-26

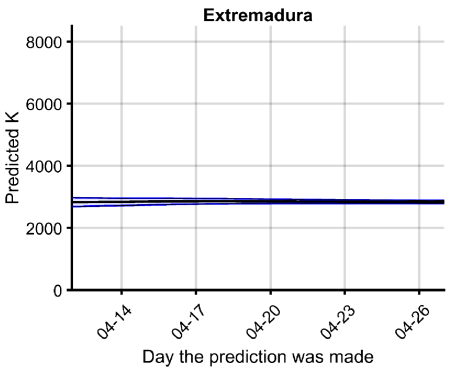

Comunitat Valenciana
×10^4
Predicted K
Day the prediction was made
04-14
04-17
04-20
04-23
04-26

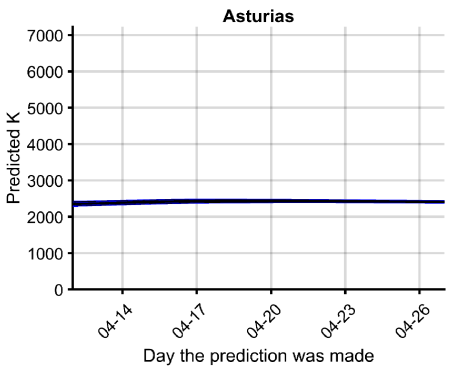

Galicia
×10^4
Predicted K
Day the prediction was made
04-14
04-17
04-20
04-23
04-26

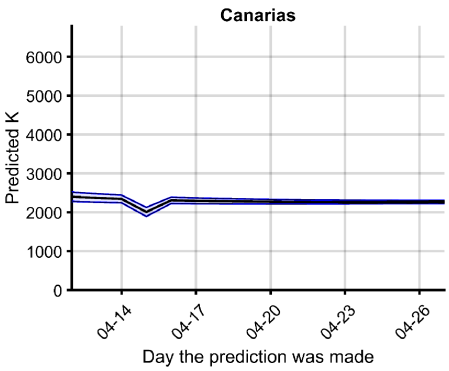

Navarra
Predicted K
Day the prediction was made
04-14
04-17
04-20
04-23
04-26

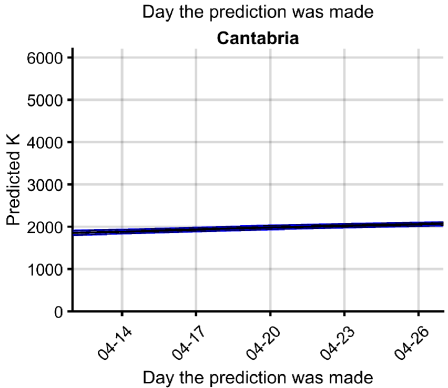

Aragon
Predicted K
Day the prediction was made
04-14
04-17
04-20
04-23
04-26

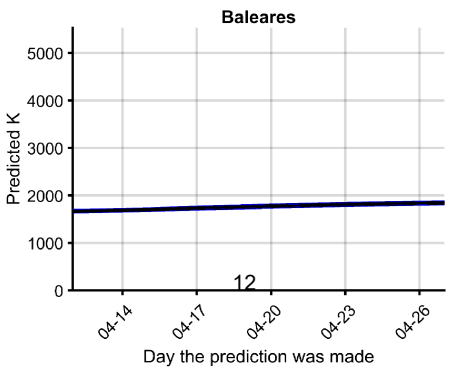

La Rioja
Predicted K
Day the prediction was made
04-14
04-17
04-20
04-23
04-26

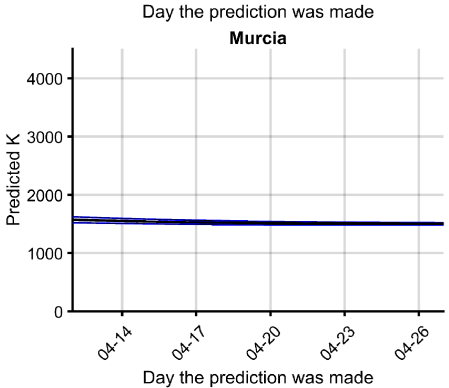

Extremadura
Predicted K
Day the prediction was made
04-14
04-17
04-20
04-23
04-26


Asturias
Predicted K
Day the prediction was made
04-14
04-17
04-20
04-23
04-26


Canarias
Predicted K
Day the prediction was made
04-14
04-17
04-20
04-23
04-26


Cantabria
Predicted K
Day the prediction was made
04-14
04-17
04-20
04-23
04-26


Baleares
Predicted K
Day the prediction was made
04-14
04-17
04-20
04-23
04-26


Murcia
Predicted K
Day the prediction was made
04-14
04-17
04-20
04-23
04-26

Situation and trends in Italian and Spanish regions

Italy

	Reported data						Indexes		
Country	Cumulative cases	Attack rate / 10^5 inh.	Cumulative deaths	Mortality / 10^5 inh.	Active cases (last 14 days)	14-day attack rate / 10^5 inh	ρ_7 (1)	EPG_{REP} (2)	EPG_{EST} (3)
Lombardia	75,134	748.2	13,679	136.2	12,981	129.3	0.90	117	2,211
Piemonte	25,861	593.6	3,003	68.9	7,632	175.2	0.84	147	1,827
Emilia Romagna	25,177	564.6	3,512	78.8	4,148	93.0	0.79	74	1,057
Veneto	17,825	363.3	1,437	29.3	3,201	65.2	0.65	43	370
Toscana	9,292	249.1	827	22.2	1,626	43.6	0.74	32	301
Liguria	7,889	508.8	1,152	74.3	1,953	125.9	1.01	127	2,007
Lazio	6,545	111.3	431	7.3	1,313	22.3	0.91	20	140
Marche	6,210	407.1	899	58.9	707	46.4	0.78	36	543
Campania	4,410	76.0	359	6.2	603	10.4	0.71	7	61
Trento	4,069	379.5	416	38.8	849	79.2	1.07	85	1,822
Puglia	4,029	100.0	410	10.2	845	21.0	0.63	13	144
Sicilia	3,140	62.8	232	4.6	605	12.1	0.84	10	80
Friuli Venezia Giulia	3,010	247.7	285	23.5	466	38.3	0.92	35	338
Abruzzo	2,923	222.9	315	24.0	649	49.5	0.54	27	289
Bolzano	2,507	2,333.5	274	255.0	283	263.4	0.60	157	364
Umbria	1,391	157.7	66	7.5	69	7.8	0.94	7	ND
Sardegna	1,290	78.7	116	7.1	129	7.9	0.59	5	45
Valle dAosta	1,124	894.9	137	109.1	166	132.2	1.03	136	1,681
Calabria	1,102	56.6	86	4.4	131	6.7	0.65	4	ND
Basilicata	366	65.0	25	4.4	46	8.2	0.80	7	ND
Molise	297	97.2	21	6.9	34	11.1	0.87	10	ND

	Scale								
	Worst	Worst	Worst	Worst	Worst	Worst	2.0	500	2500
	Best	Best	Best	Best	Best	Best	0.0	0	0

Spain

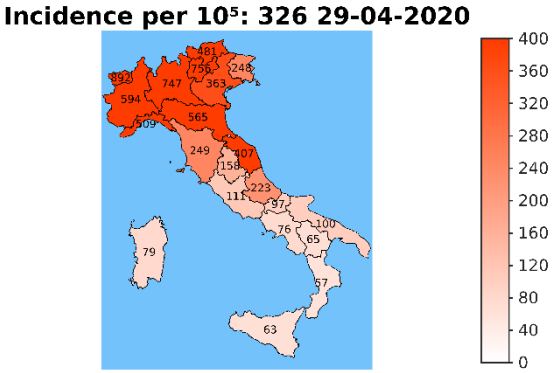
	Reported data						Indexes		
Autonomous regions	Cumulative cases	Attack rate /10^5 inh.	Cumulated deaths	Mortality rate /10^5 inh.	Active cases (last 14 days)	14-day attack rate /10^5 inh.	ρ_7 (1)	EPG_{REP} (2)	EPG_{EST} (3)
Madrid	60,765	915.0	8,105	122.1	11,239	169.2	0.73	124	1,720
Catalunya	48,654	643.1	4,905	64.8	12,149	160.6	0.72	116	1,243
Castilla y Leon	16,690	693.1	1,736	72.1	3,259	135.3	0.99	134	1,474
Castilla-La Mancha	15,785	775.5	2,436	119.7	1,478	72.6	1.33	97	1,540
Euskadi	12,619	579.4	1,274	58.5	1,284	59.0	3.81	224	2,459
Andalucia	12,004	142.5	1,188	14.1	1,578	18.7	0.93	17	189
Comunitat Valenciana	10,236	205.8	1,218	24.5	903	18.2	1.00	18	227
Galicia	8,675	321.3	547	20.3	967	35.8	3.70	133	809
Aragon	5,042	381.7	736	55.7	704	53.3	0.8	41	636
Navarra	4,794	737.6	448	68.9	570	87.7	1.0	85	853
La Rioja	3,910	1,246.9	330	105.2	453	144.5	0.98	141	1,222
Extremadura	2,764	259.4	440	41.3	202	19.0	0.87	17	270
Asturias	2,266	221.7	266	26.0	224	21.9	0.42	9	116
Canarias	2,202	99.8	134	6.1	227	10.3	0.85	9	56
Cantabria	2,146	368.9	191	32.8	323	55.5	0.75	42	403
Baleares	1,879	158.2	185	15.6	273	23.0	0.64	15	161
Murcia	1,480	99.5	130	8.7	60	4.0	0.90	4	33
Melilla	114	134.6	2	2.4	12	14.2	ND	ND	ND
Ceuta	101	119.0	4	4.7	3	3.5	ND	ND	ND

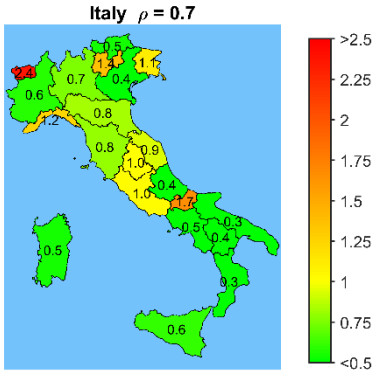
	Scale								
	Worst	Worst	Worst	Worst	Worst	Worst	2.0	500	2500
	Best	Best	Best	Best	Best	Best	0.0	0	0

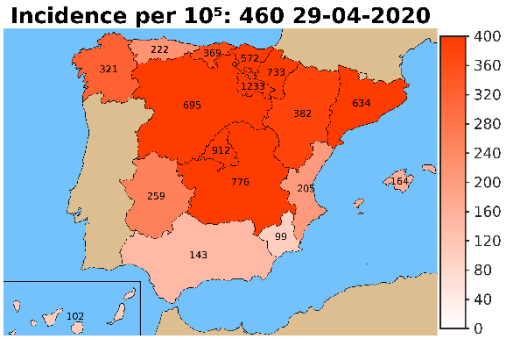
(1) ρ_3 is the average of 7 consecutive ρ, but can still fluctuate. (2) EPG stands for Effective Growth Potential. EPG_{REP} is obtained by multiplying attack rate of last 14 days per 10^5 inhabitants (i.e. density of cases) by ρ_3 (a value related with effective reproduction number and that, therefore, determines the dynamics for subsequent days). EPG_{EST} is obtained by multiplying estimated real attack rate of last 14 days per 10^5 inhabitants by ρ_3.

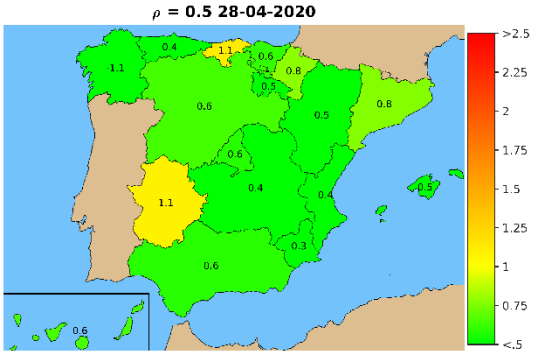
Maps of Italian and Spanish regions

Cumulative incidence and spreading rate (ρ) in Italian regions.





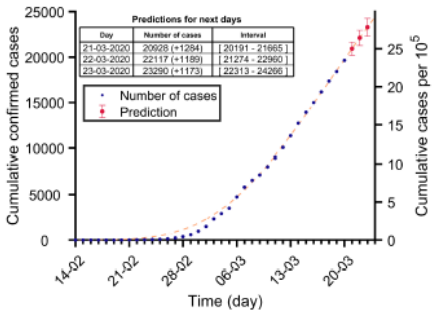


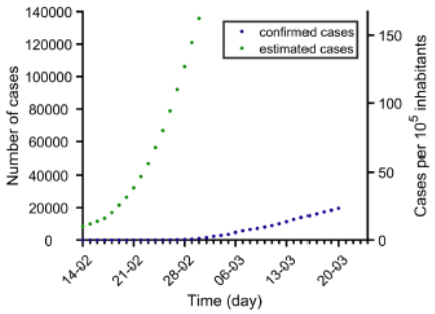


Legend: Countries' reports details

Iran 20-03-2020. Population: 83.7M. Current cumulated incidence: $23/10^5$

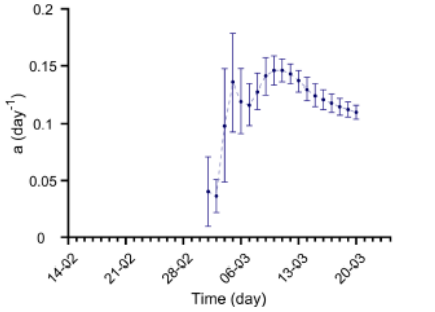
Confirmed cases: data (blue), model fitted (dashed line), predictions (red points and table)

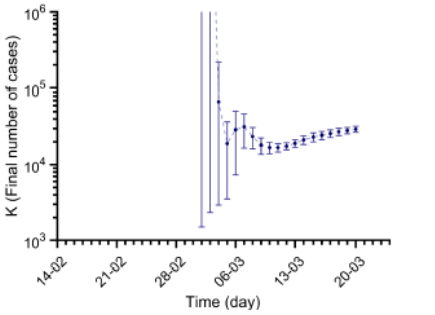




Estimated cases using death rate (see Methods)

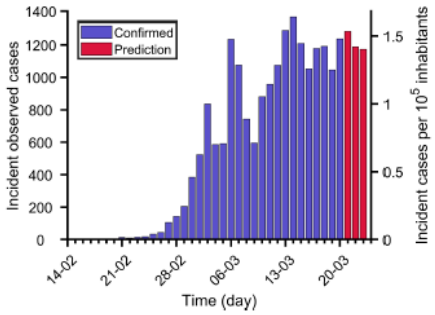
Fitted *a* value using points prior to each date

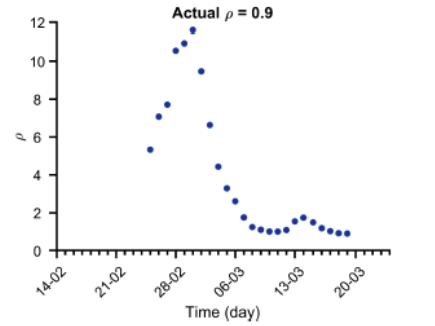




Fitted *K* value using points prior to each date

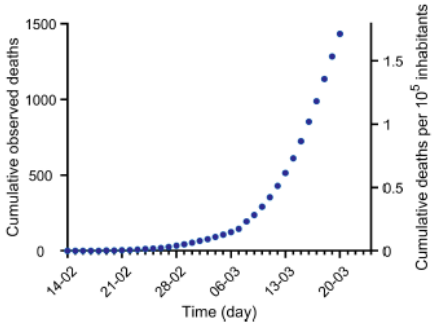
Reported and predicted new cases

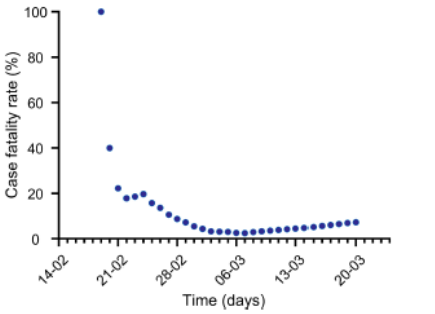




Evolution of ρ, a parameter related with Reproduction number (see Methods)

Reported deaths



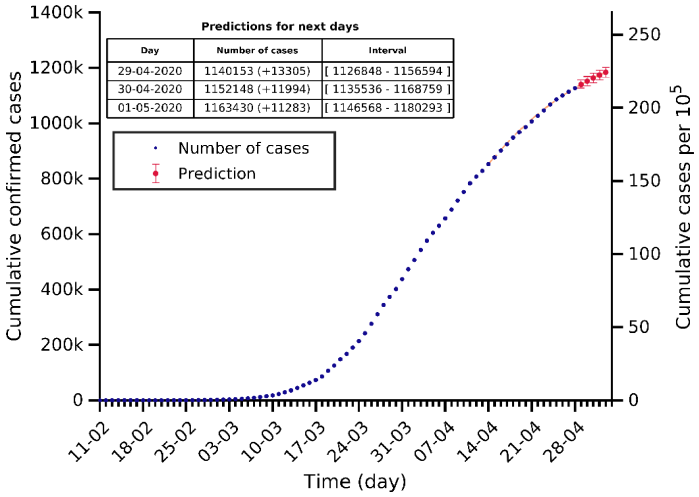


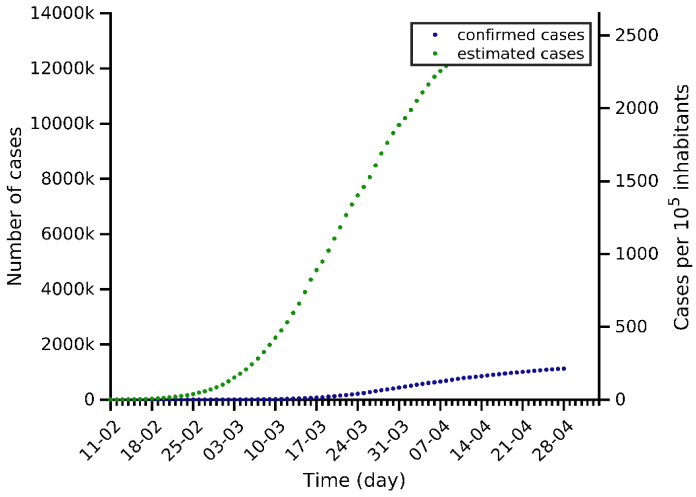
Deaths / cumulated reported cases

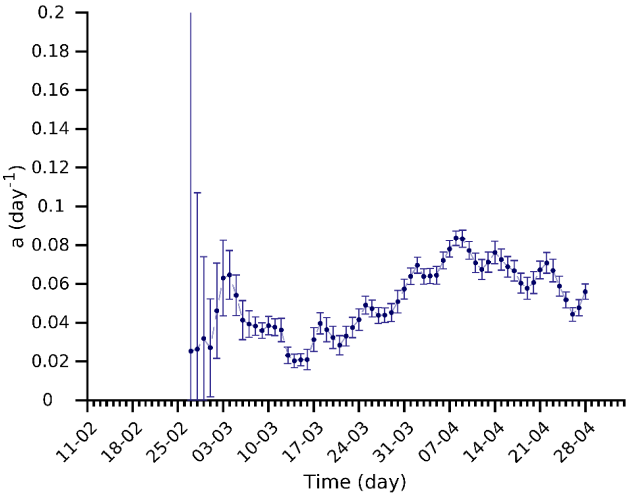
(1) Analysis and prediction of COVID-19 for EU+EFTA+UK

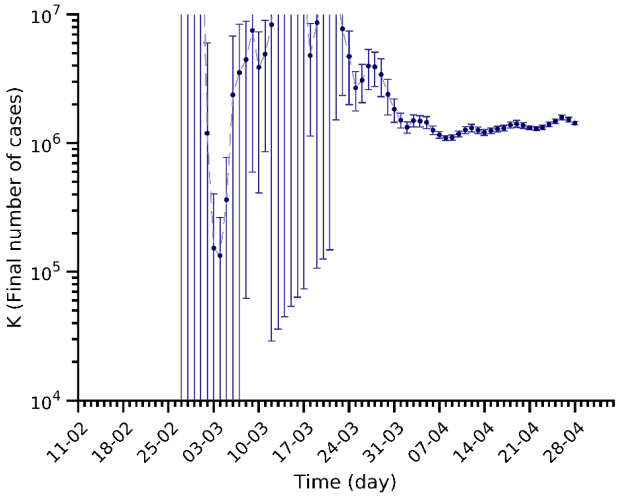
Data obtained from https://www.ecdc.europa.eu/en/geographical-distribution-2019-ncov-cases

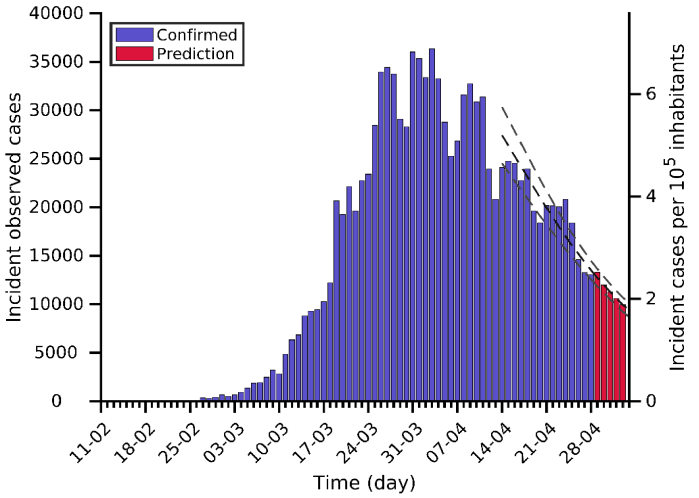
EU+EFTA+UK 28-04-2020. Population: 527.9M. Current cumulated incidence: 213/1

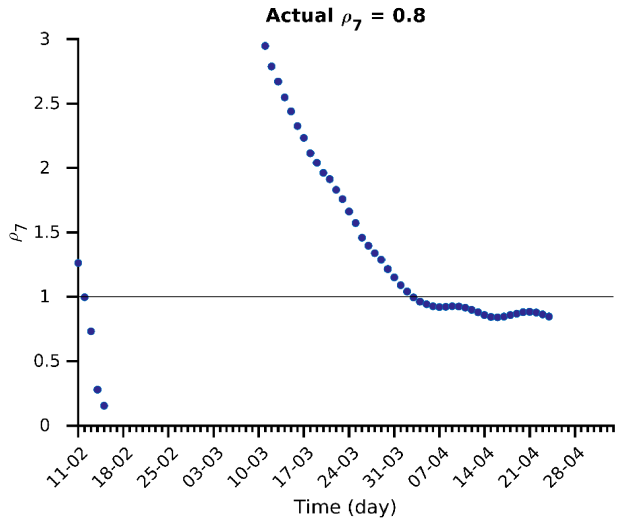


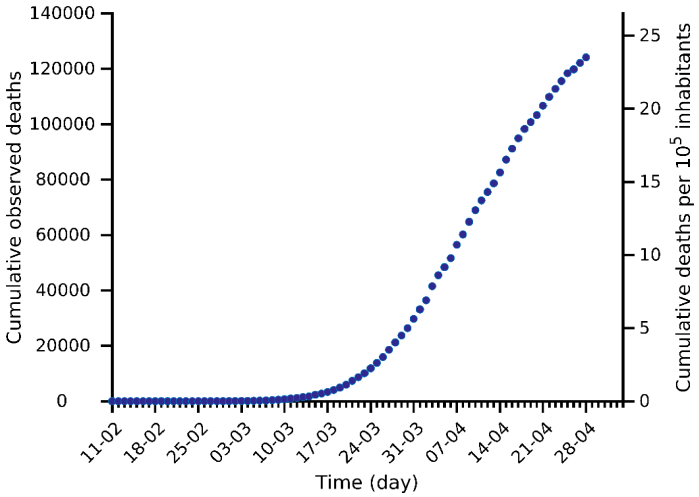


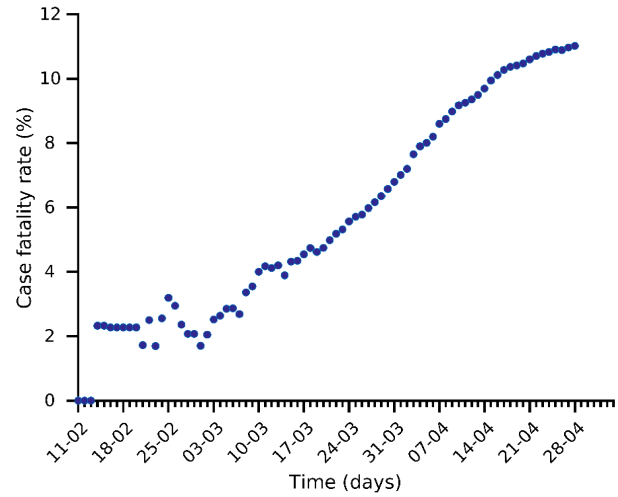




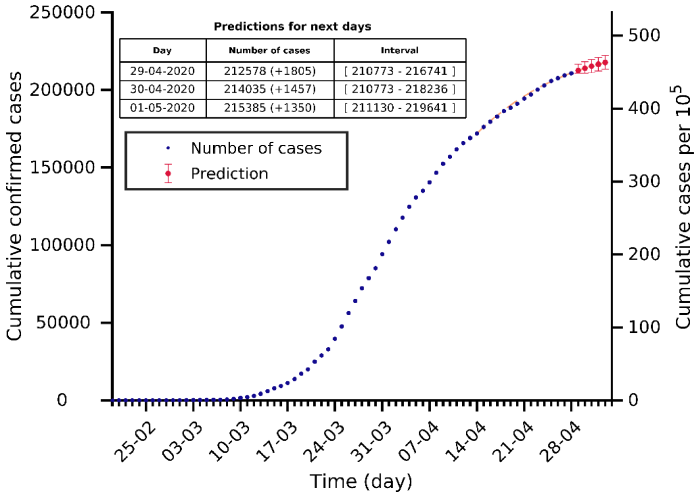


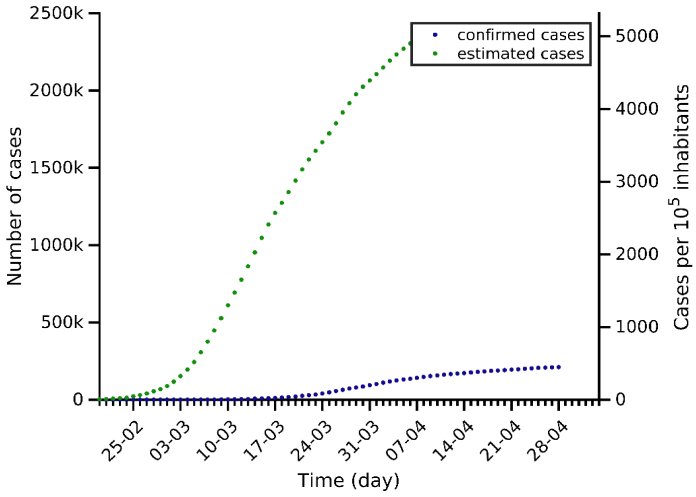


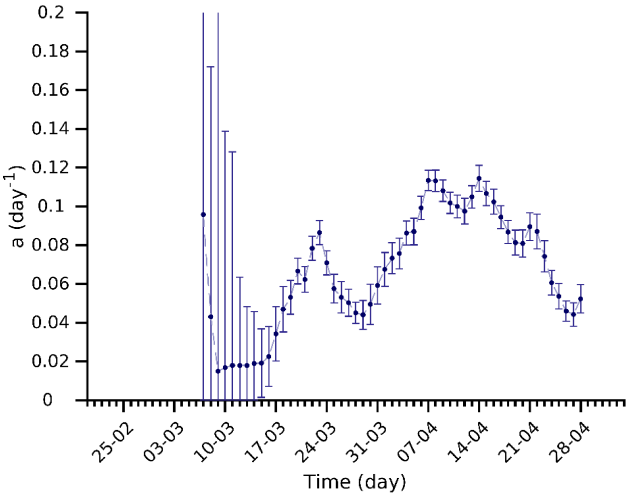


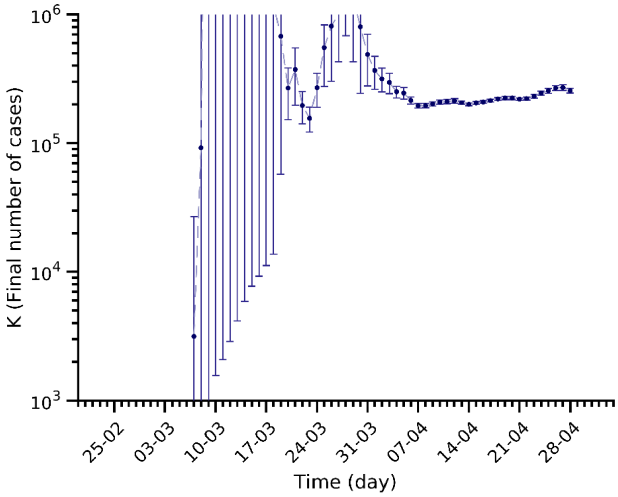


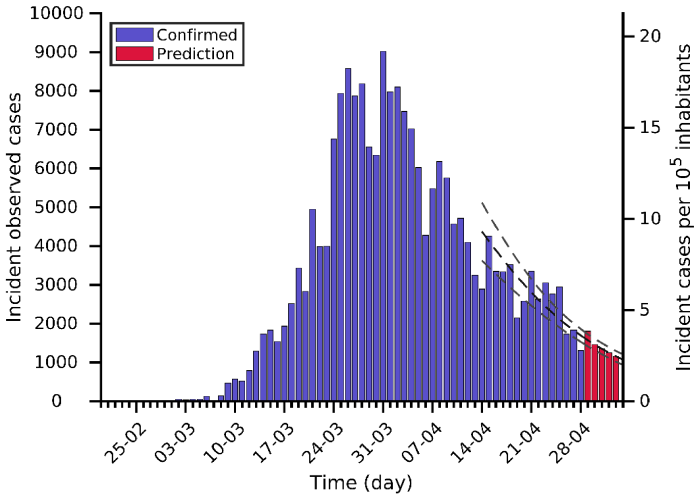
Spain 28-04-2020. Population: 47.0M. Current cumulated incidence: 448/10⁵

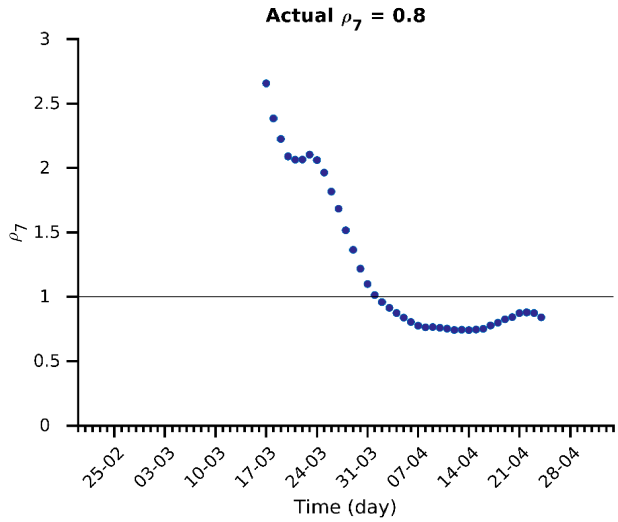


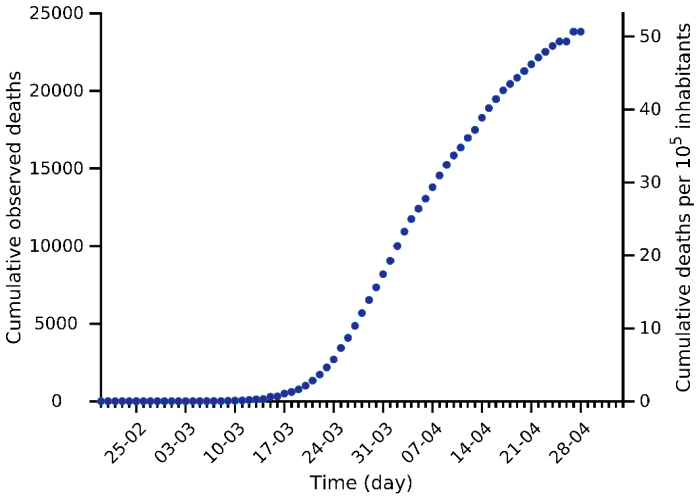


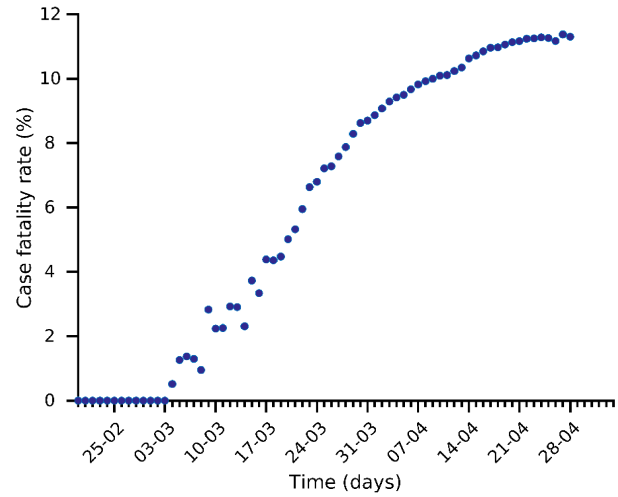




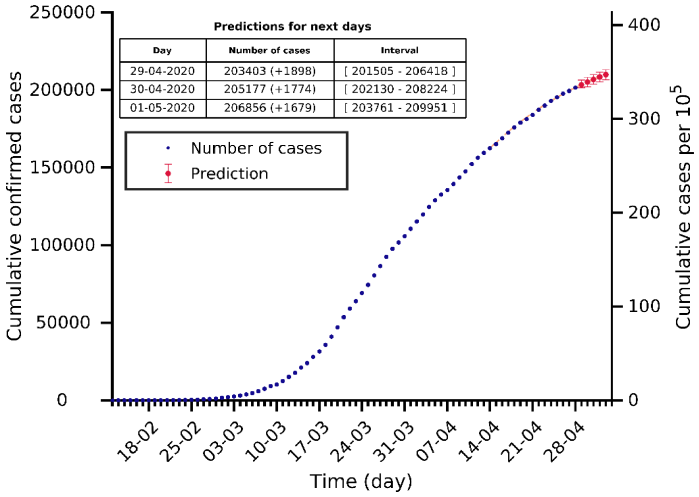


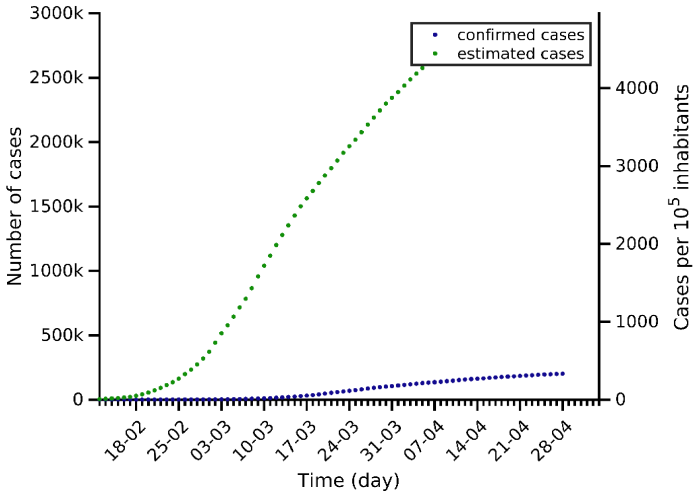


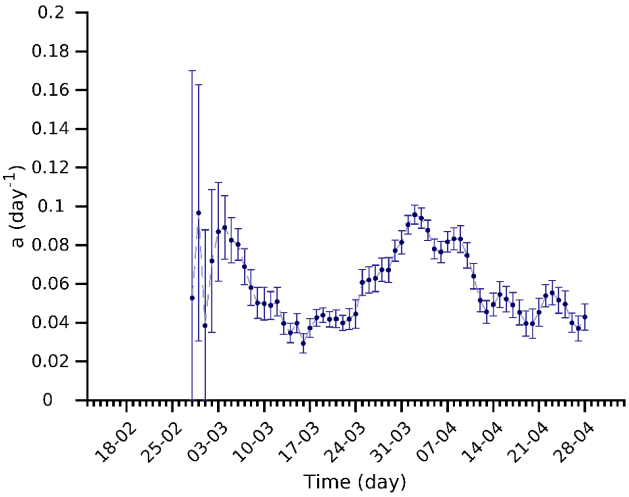


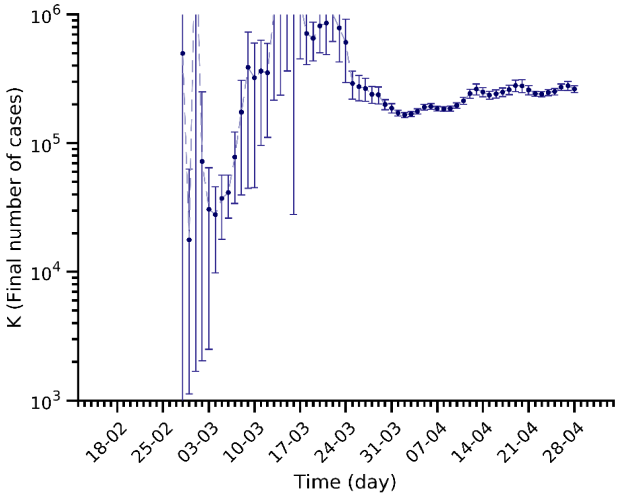


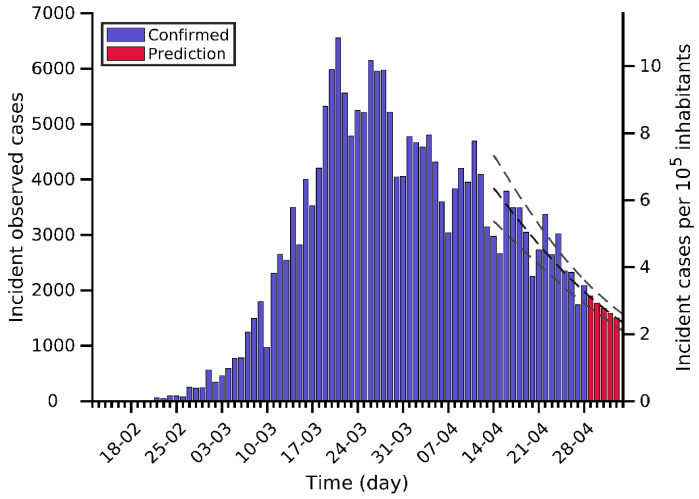
Italy 28-04-2020. Population: 60.5M. Current cumulated incidence: 333/10^5

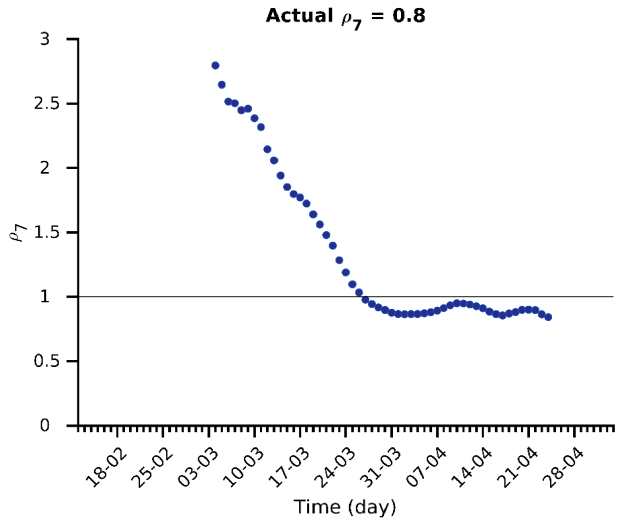


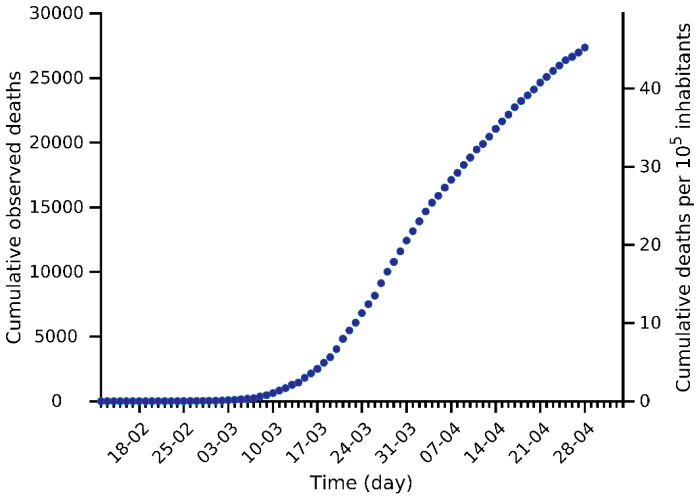


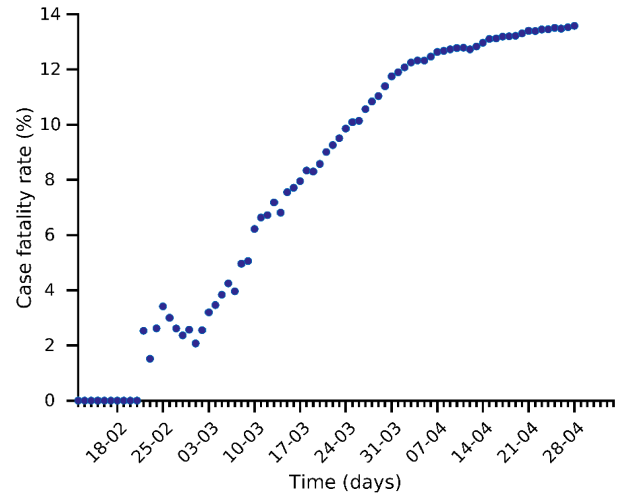




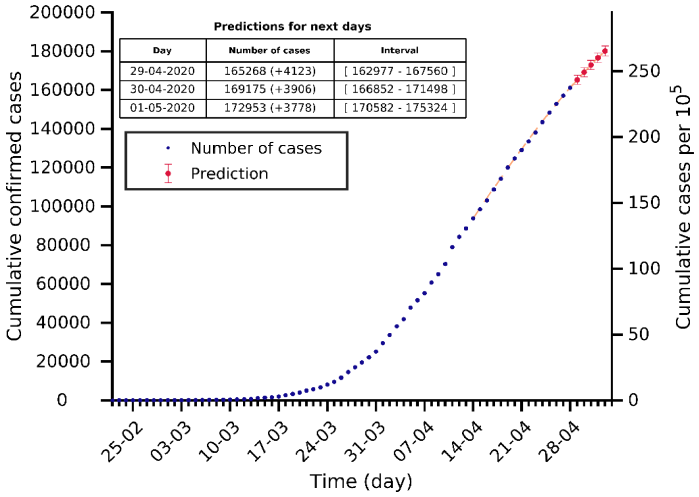


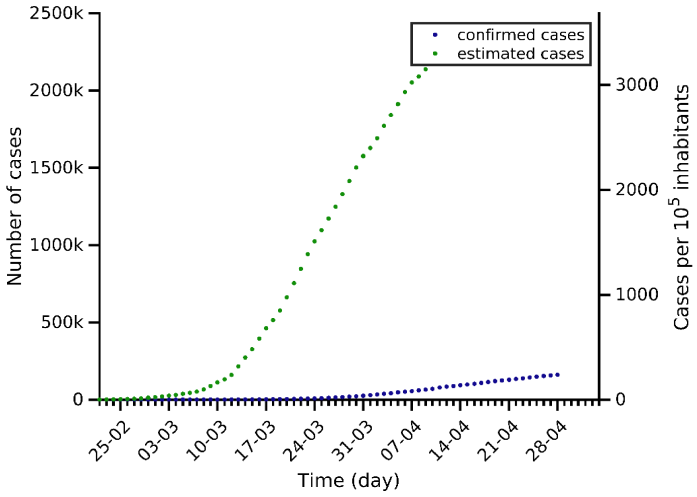


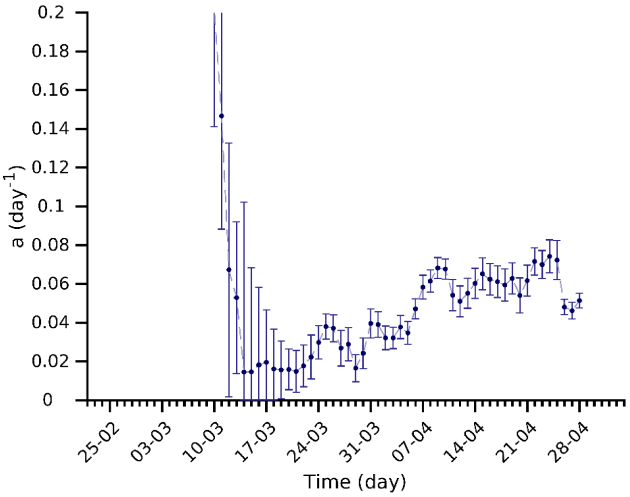


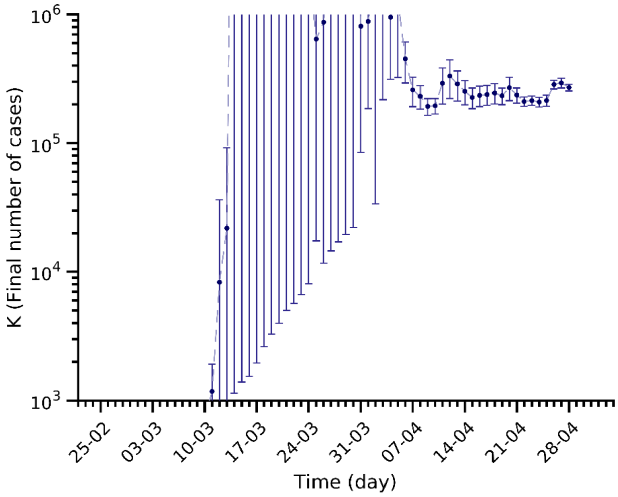


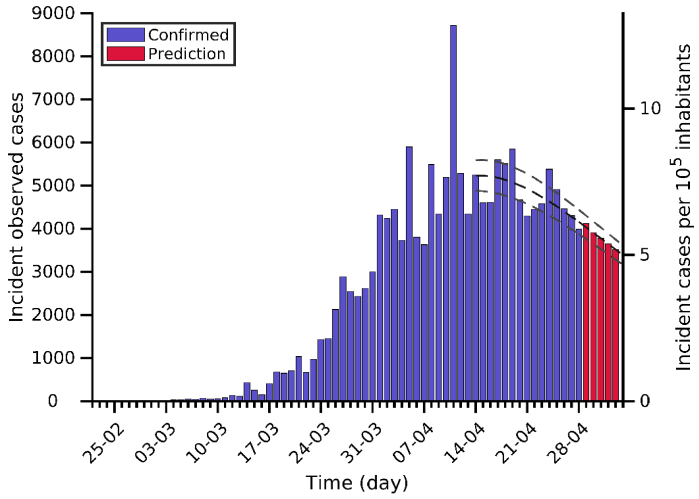
UK 28-04-2020. Population: 67.9M. Current cumulated incidence: $237/10^5$

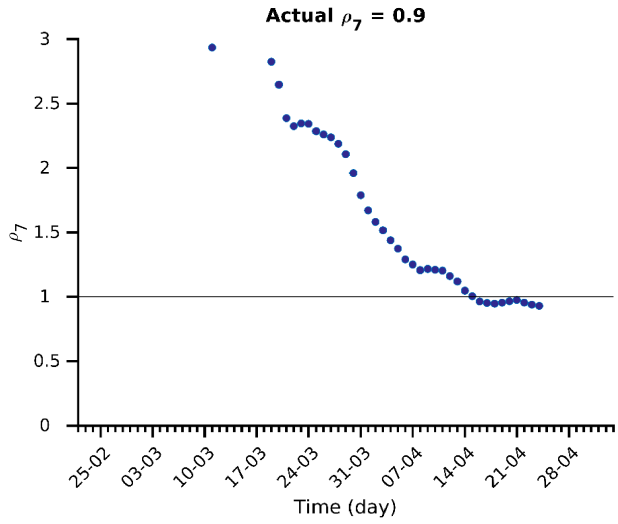


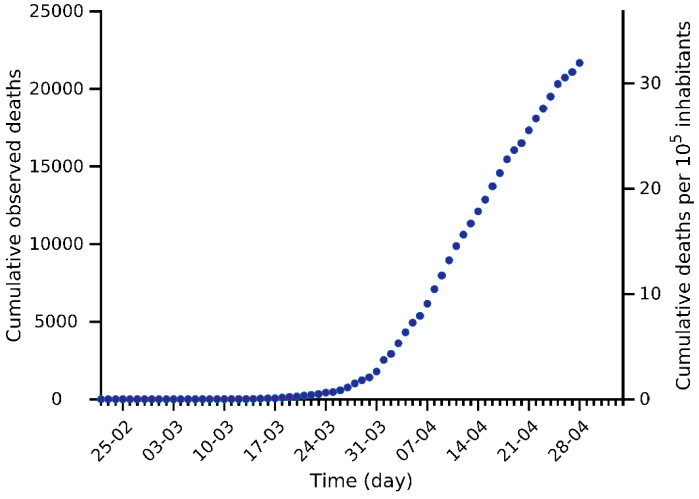


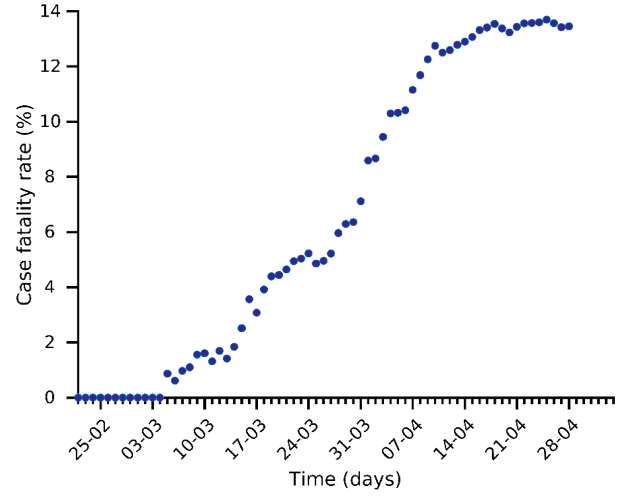




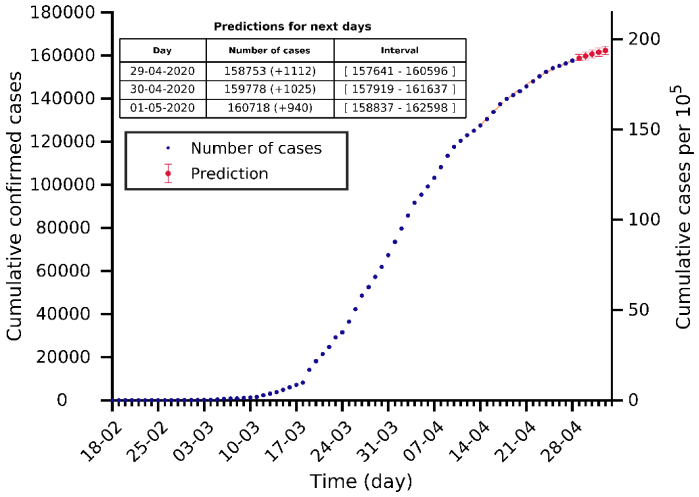


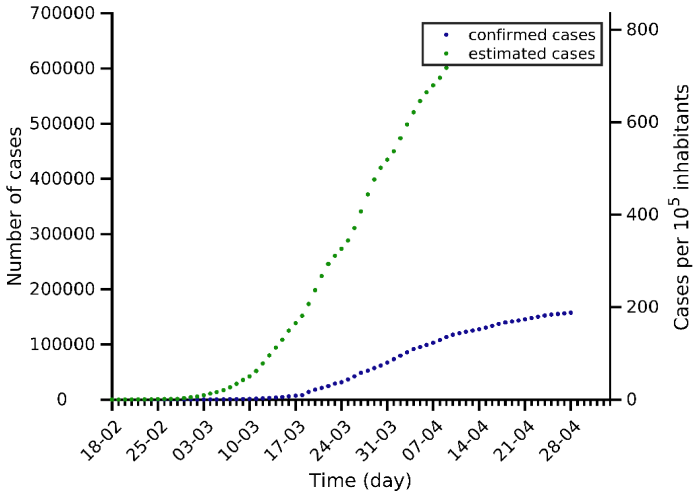


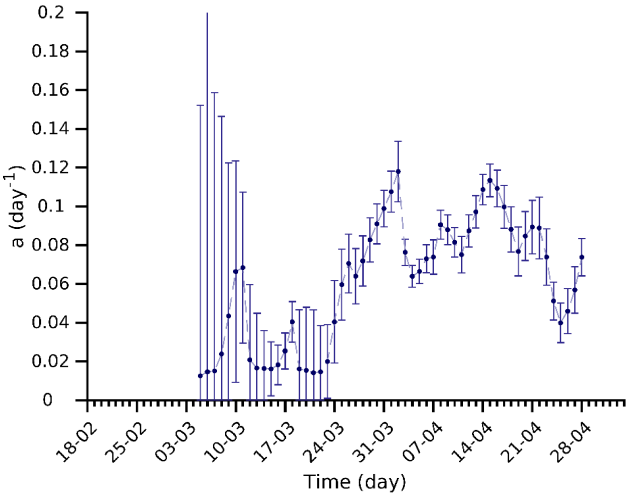


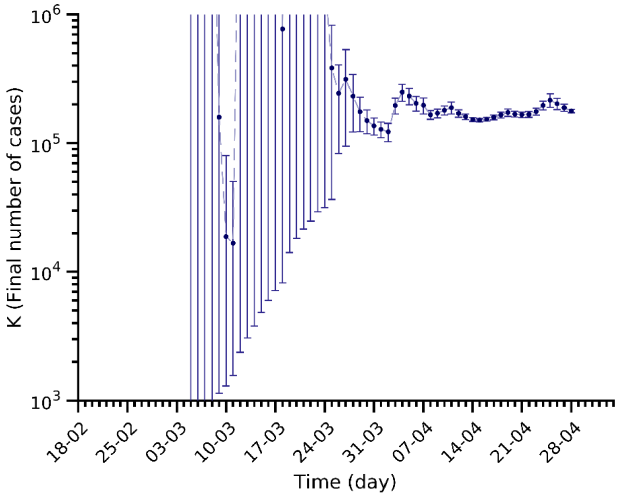


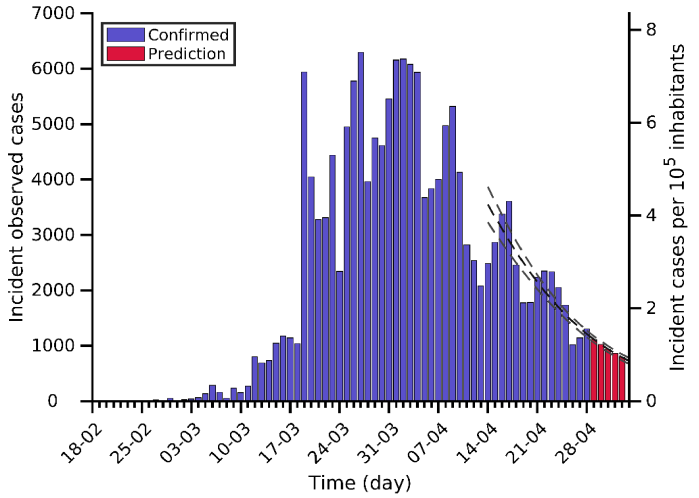
Germany 28-04-2020. Population: 83.8M. Current cumulated incidence: 188/10^5

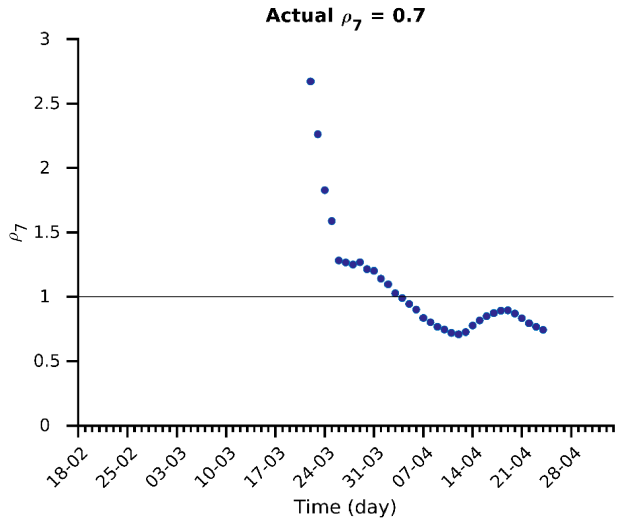


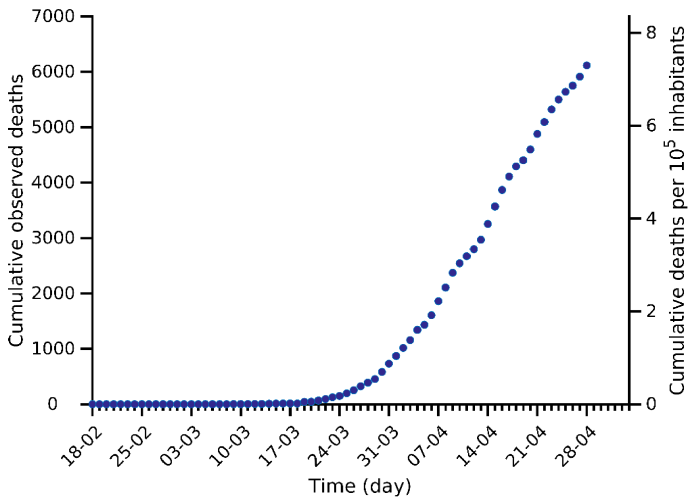


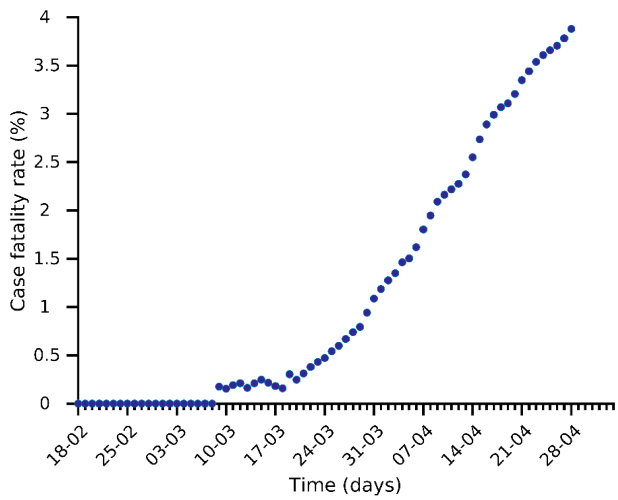




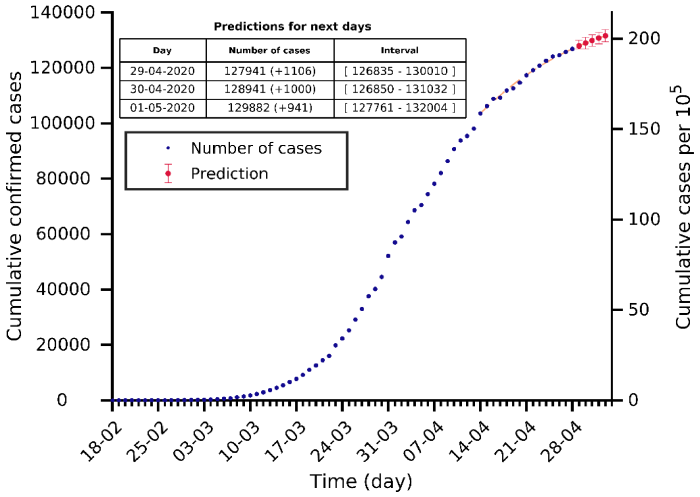


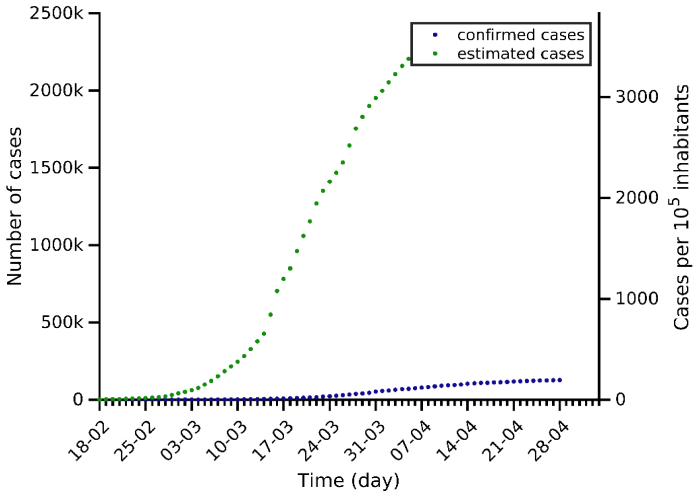


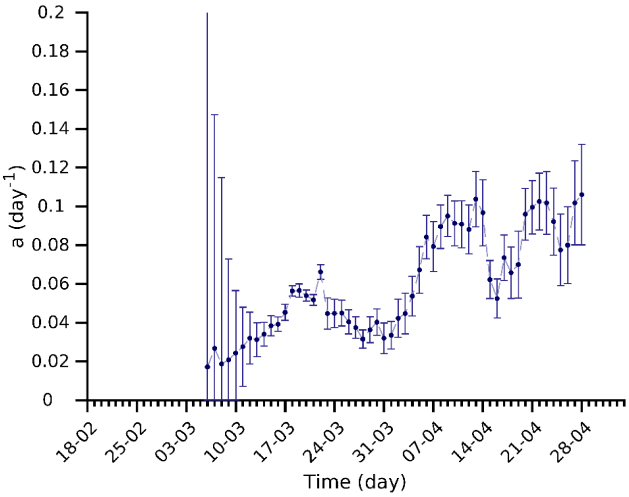


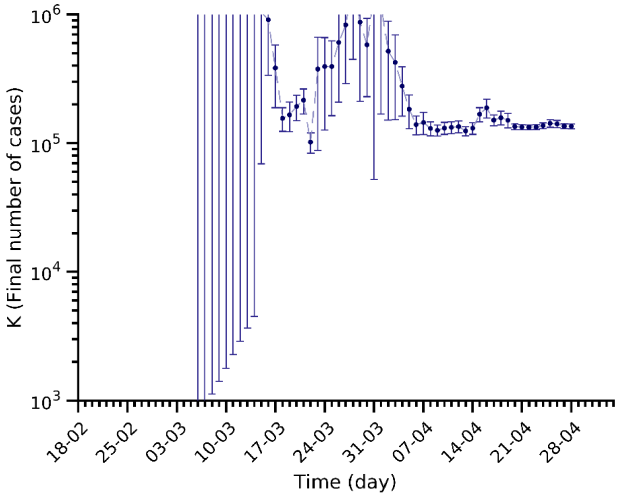


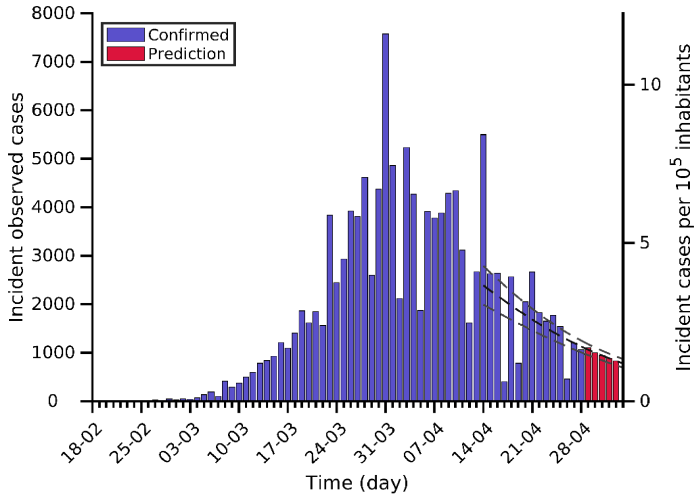
France 28-04-2020. Population: 65.3M. Current cumulated incidence: 194/10^5

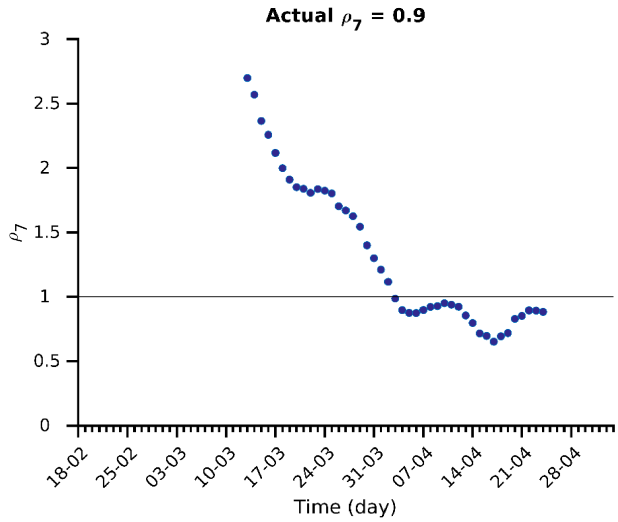


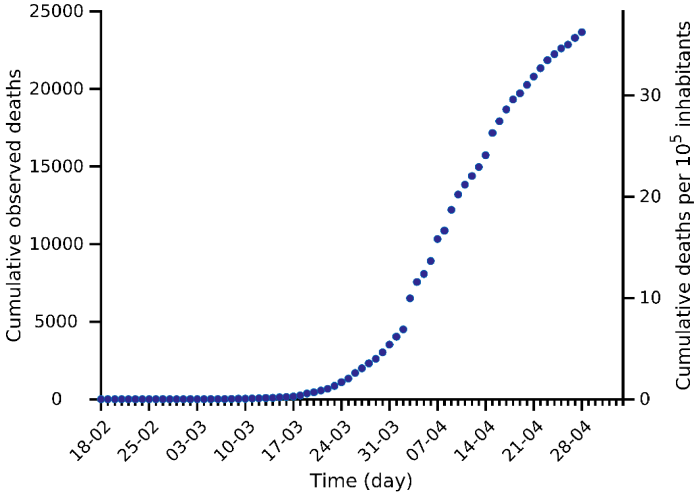


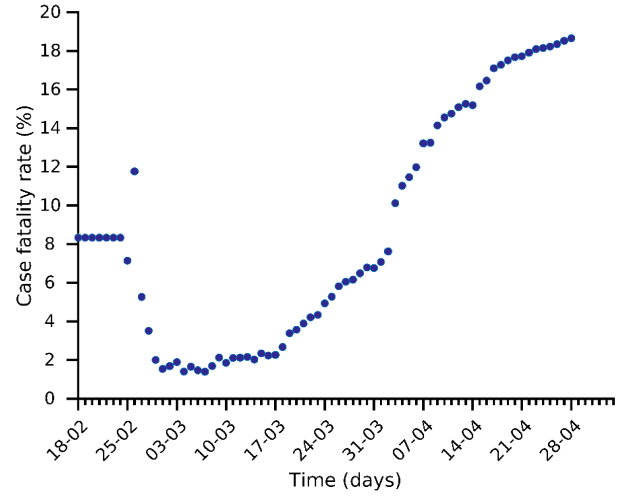




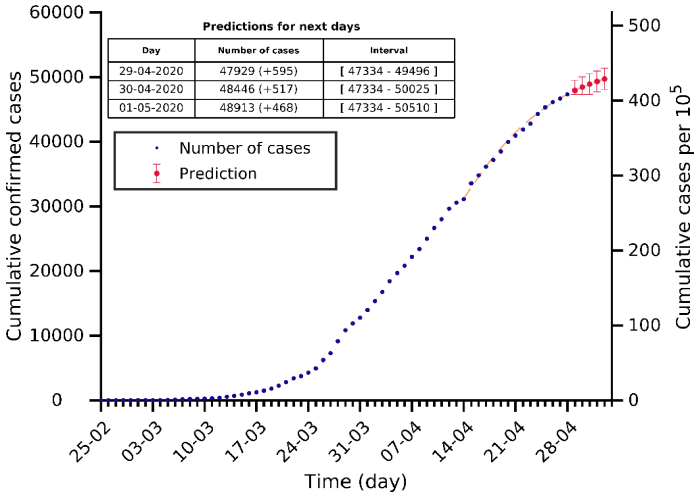


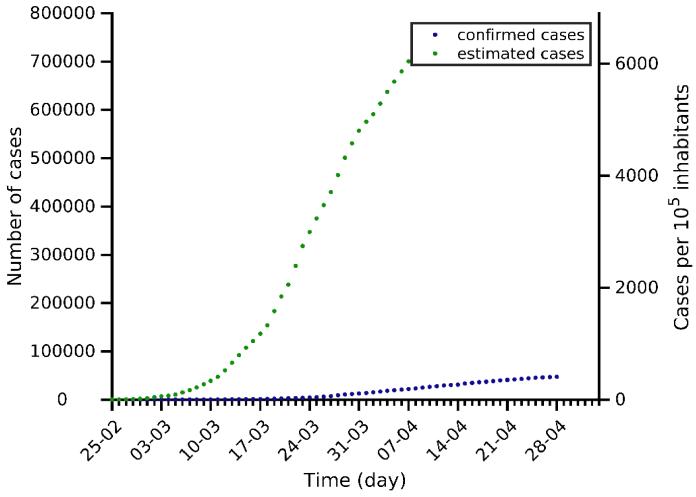


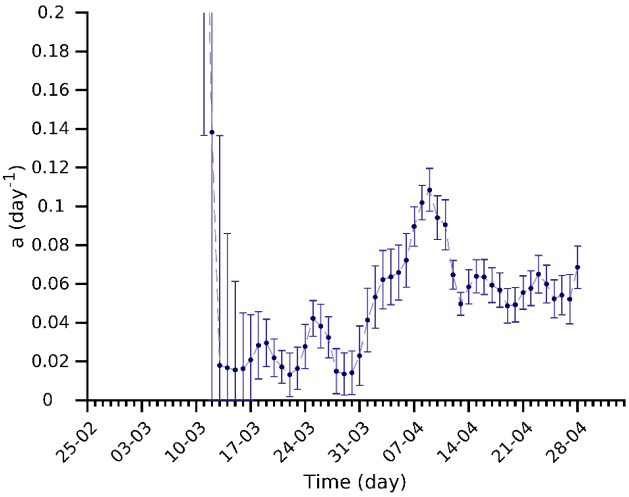


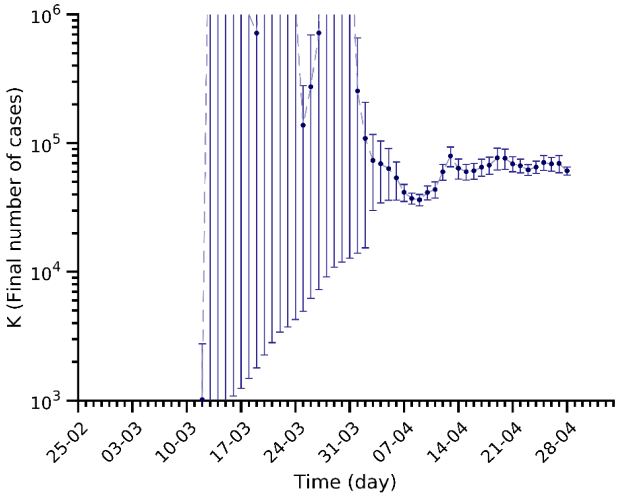


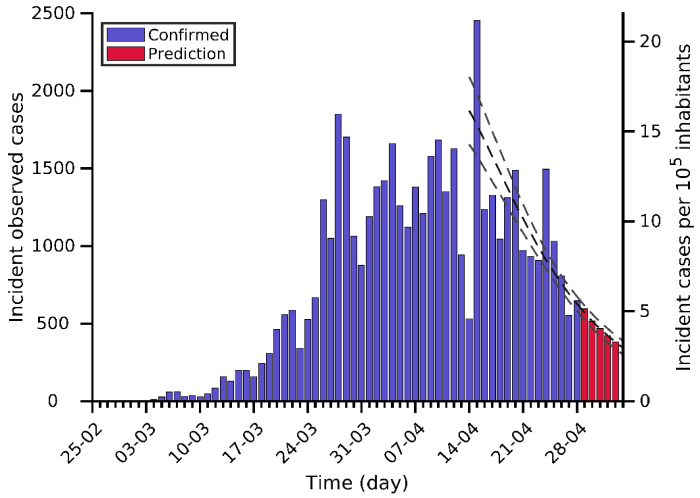
Belgium 28-04-2020. Population: 11.6M. Current cumulated incidence: 408/10^5

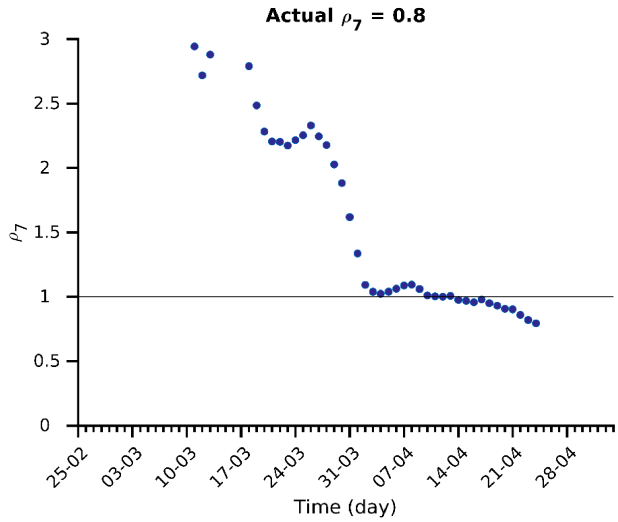


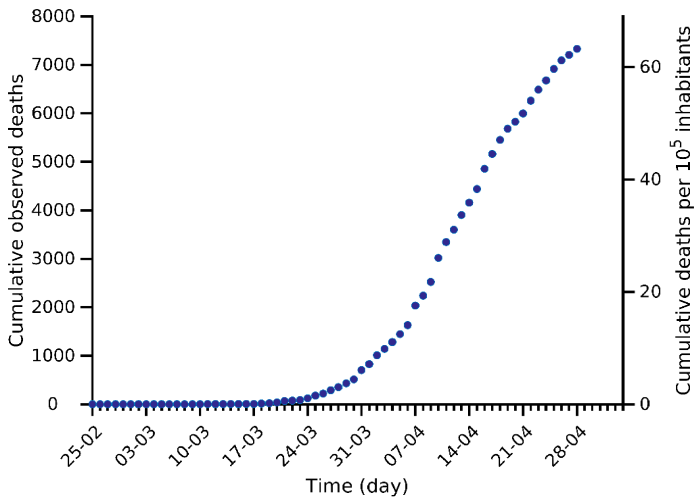


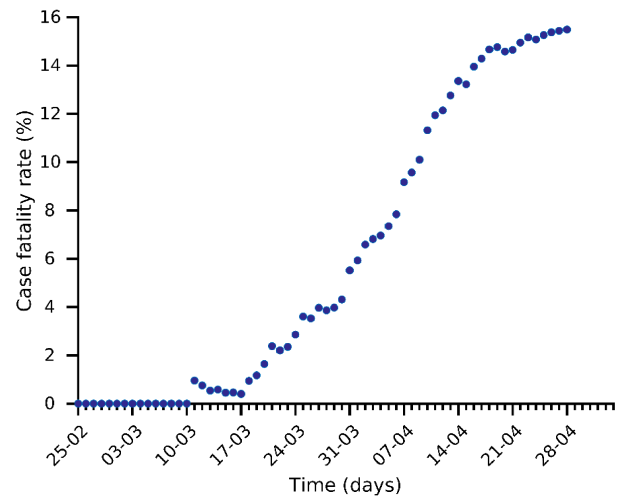




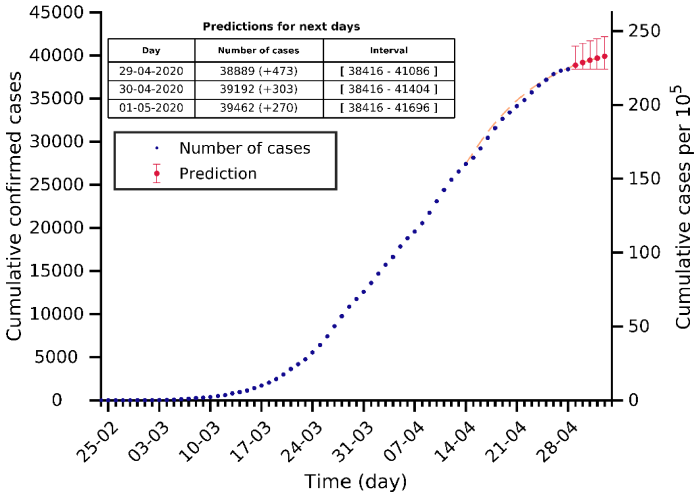


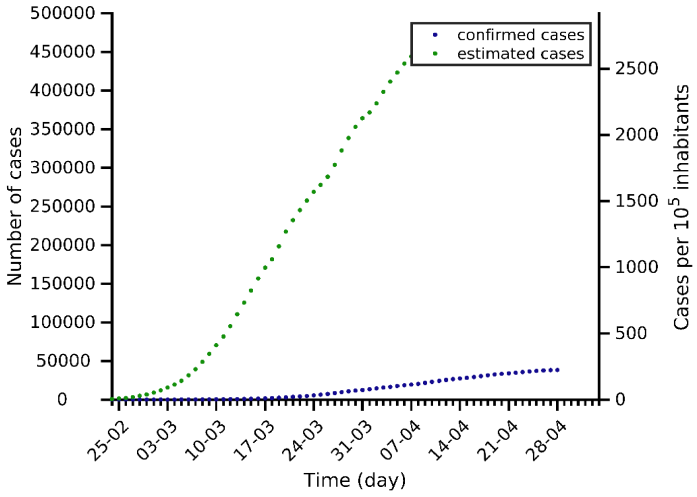


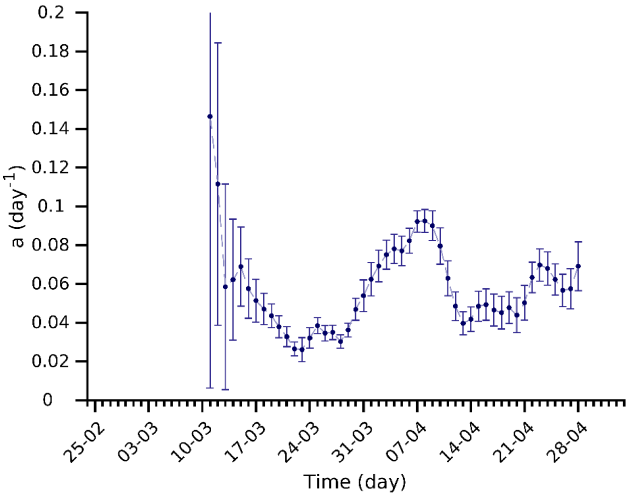


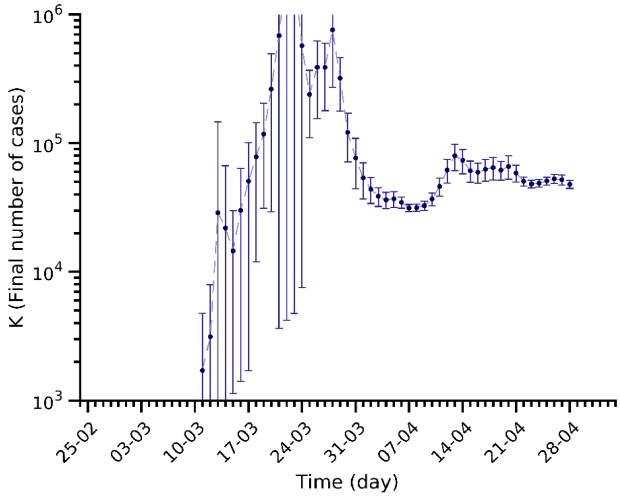


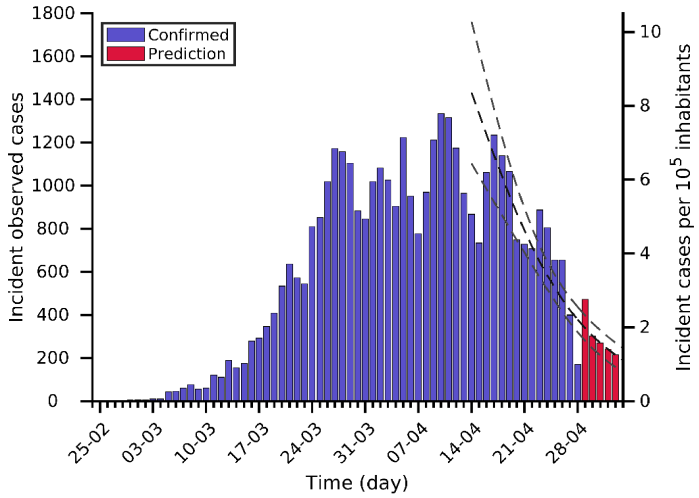
Netherlands 28-04-2020. Population: 17.1M. Current cumulated incidence: 224/10^5

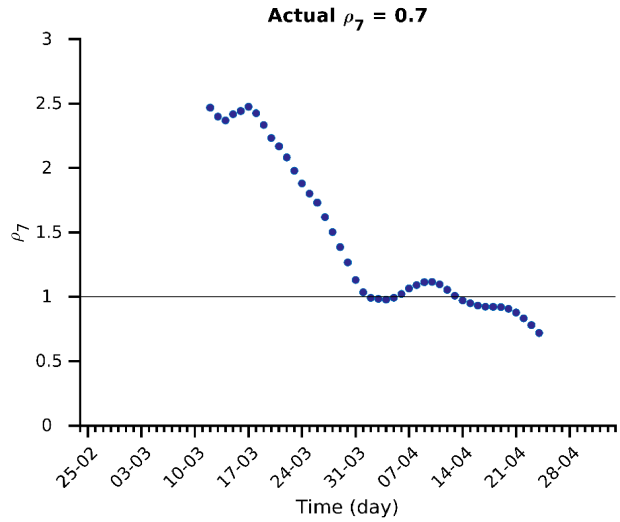


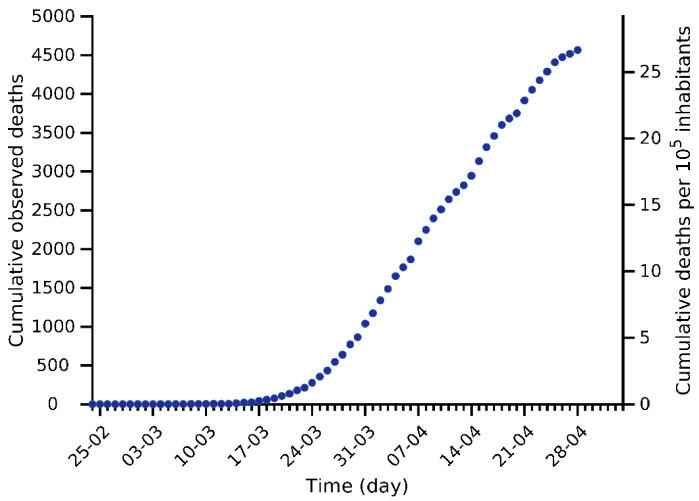


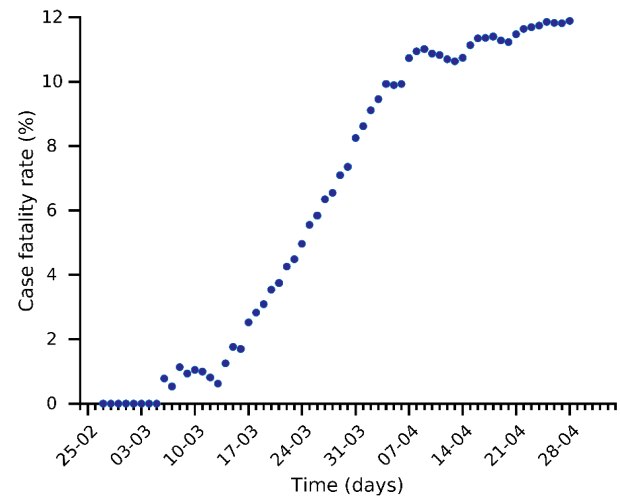




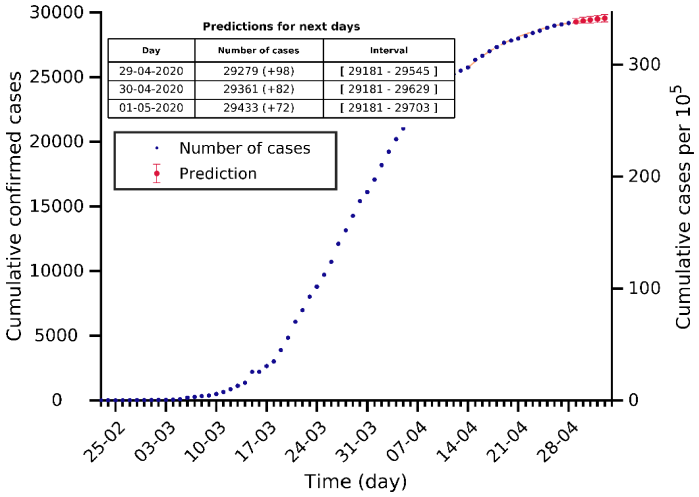


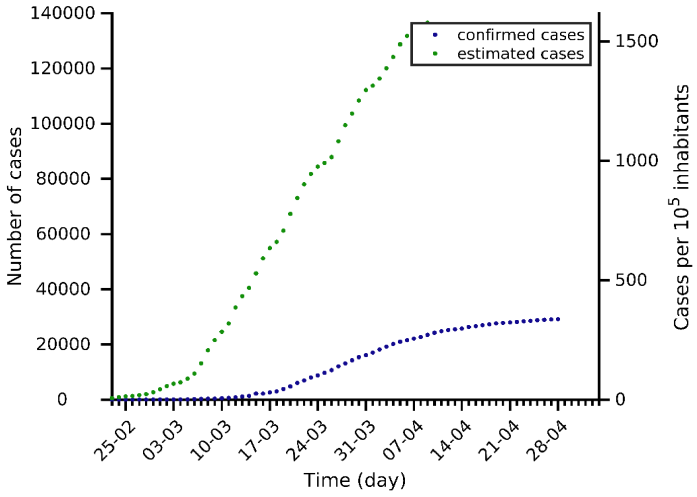


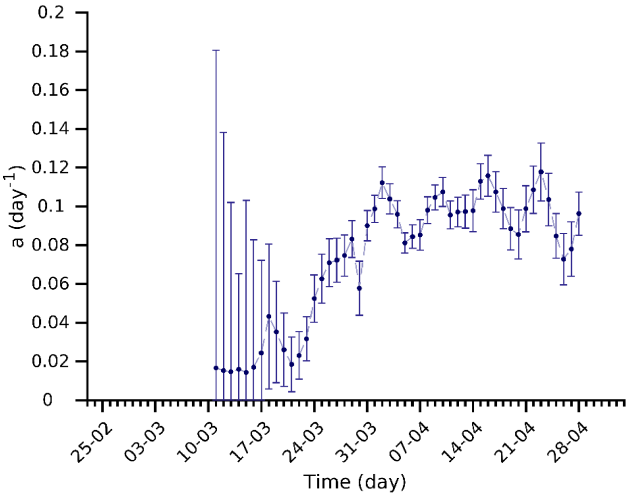


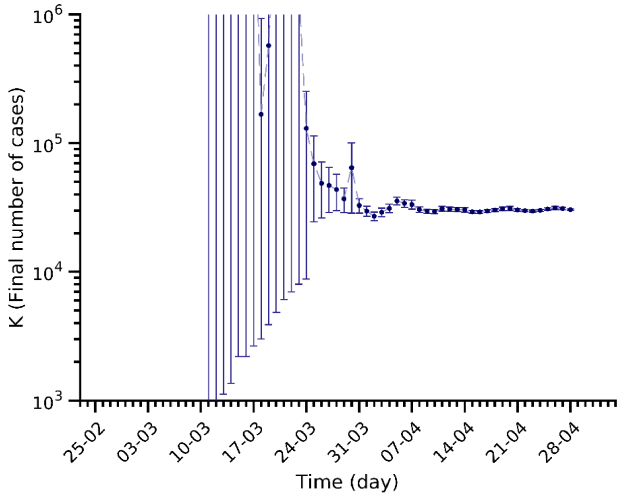


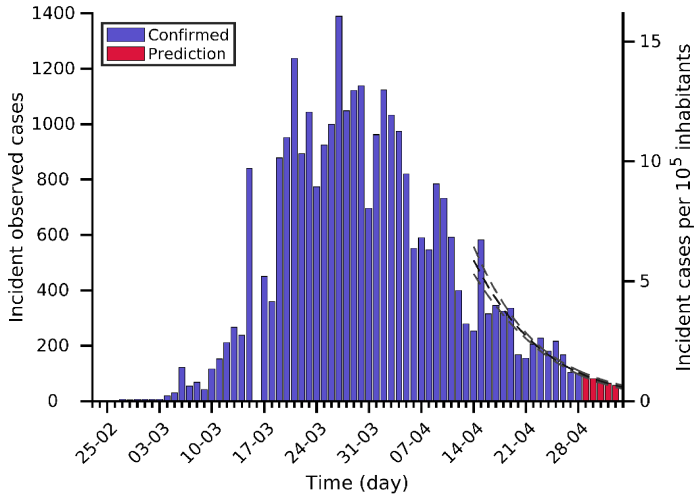
Switzerland 28-04-2020. Population: 8.7M. Current cumulated incidence: 337/10^5

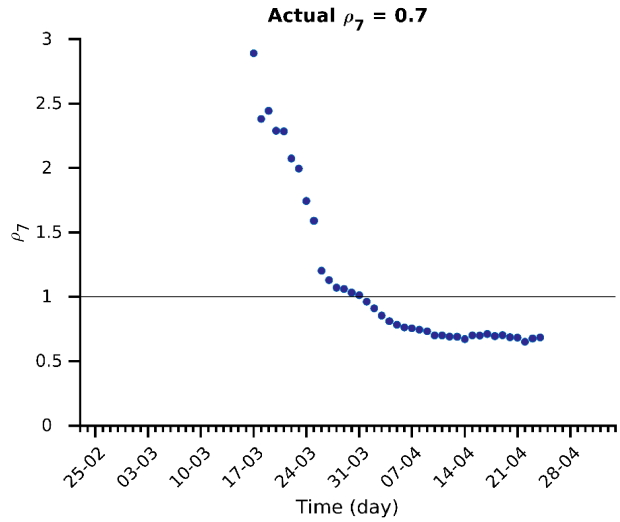


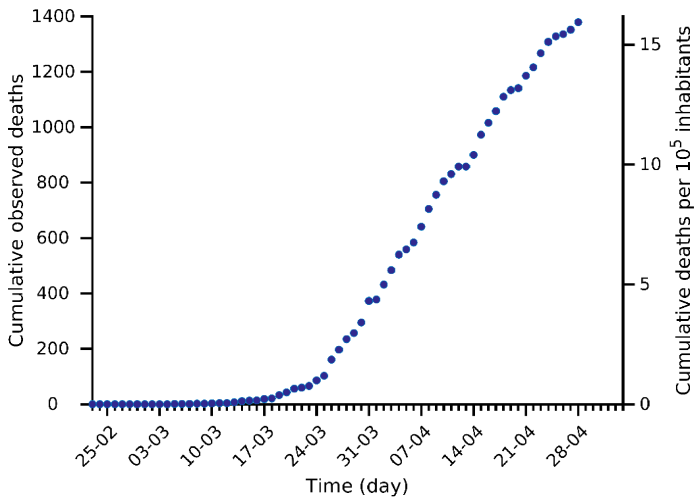


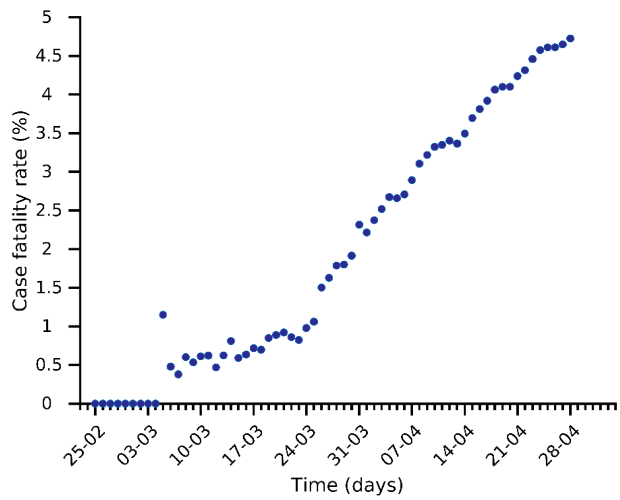




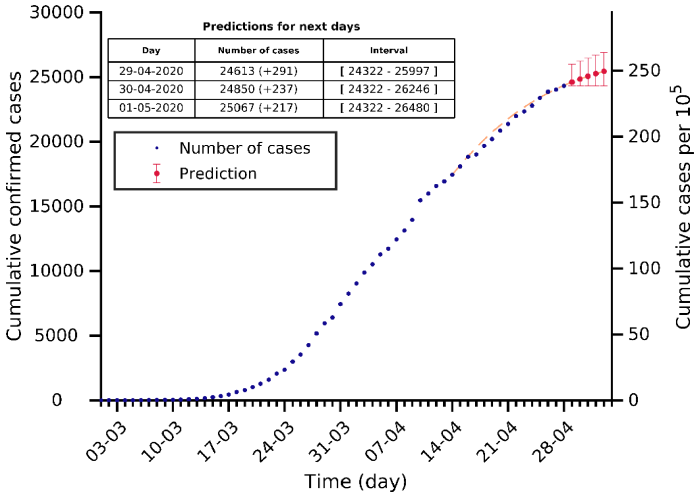


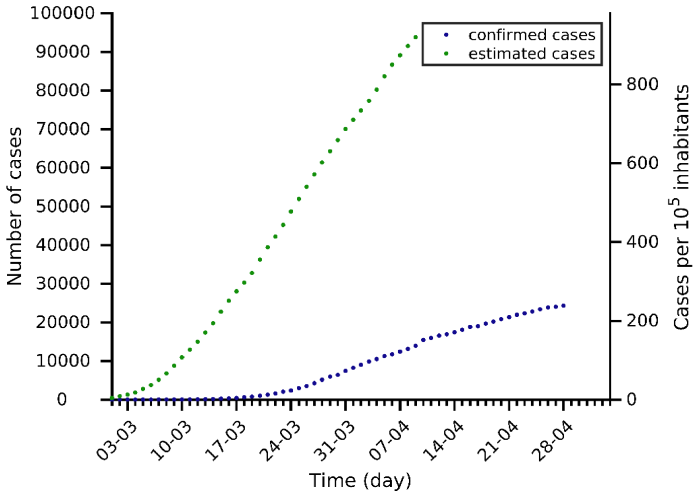


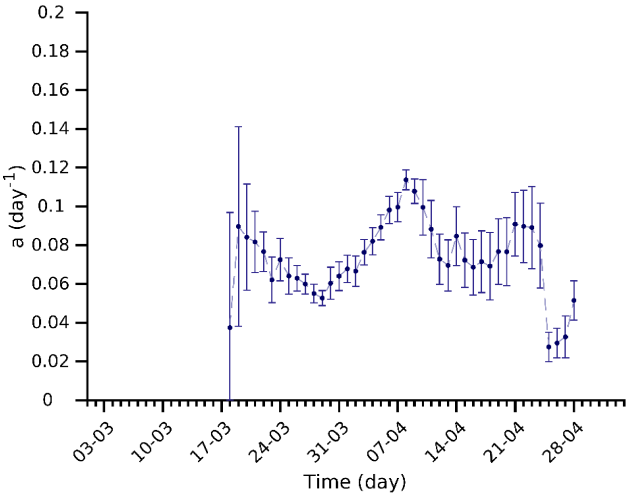


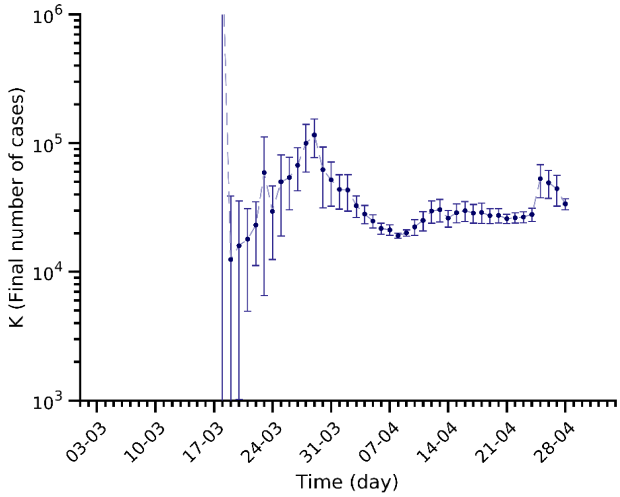


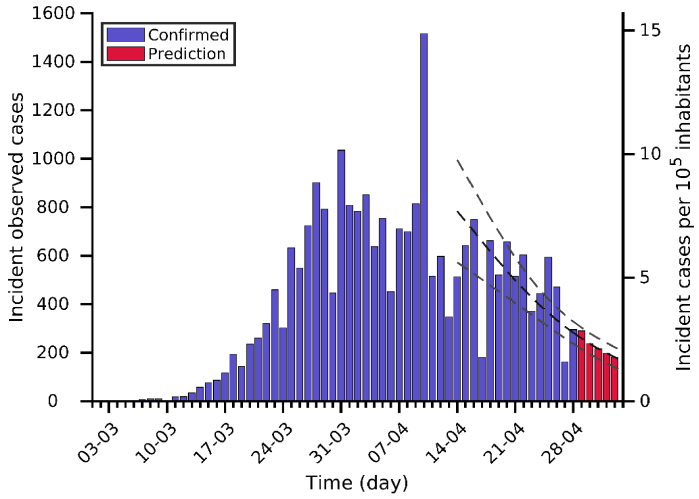
Portugal 28-04-2020. Population: 10.2M. Current cumulated incidence: $239/10^5$

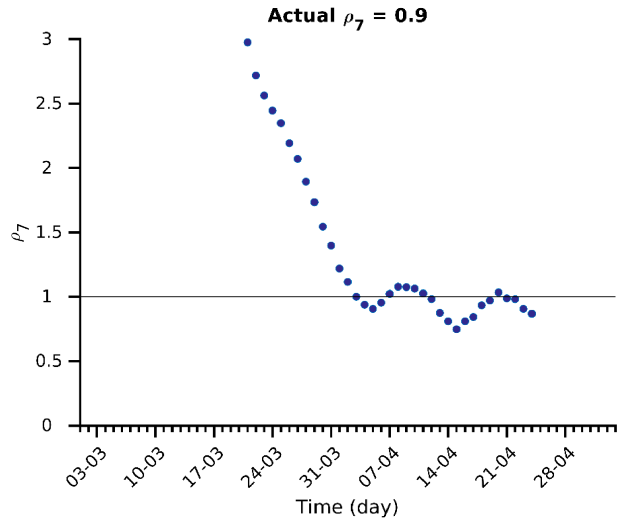


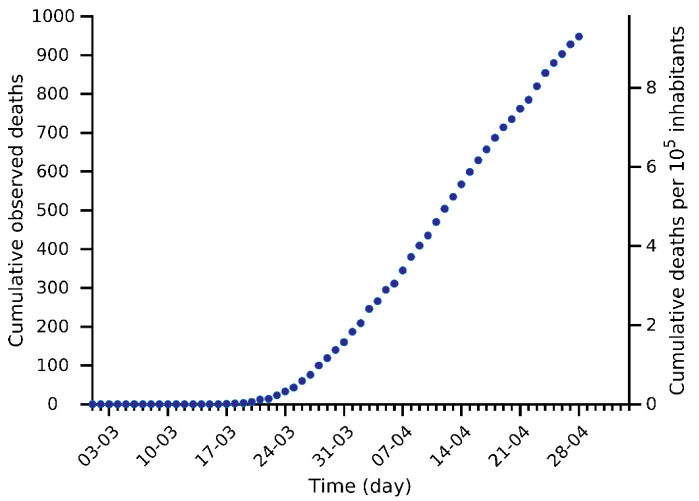


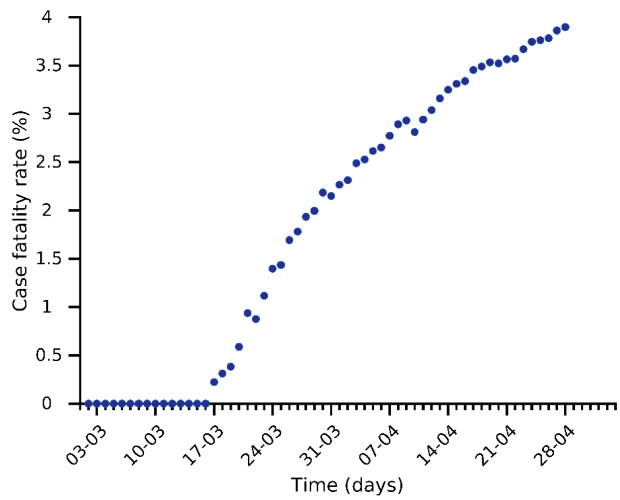




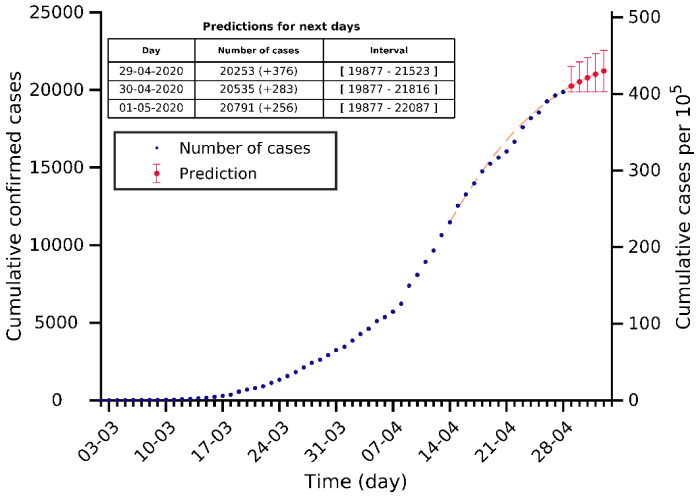


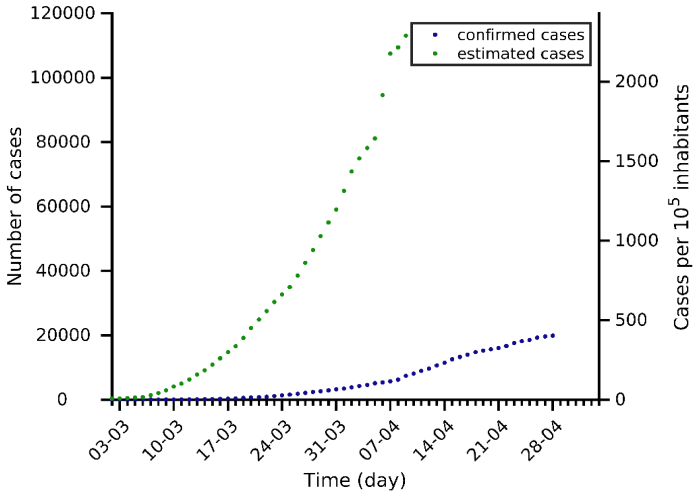


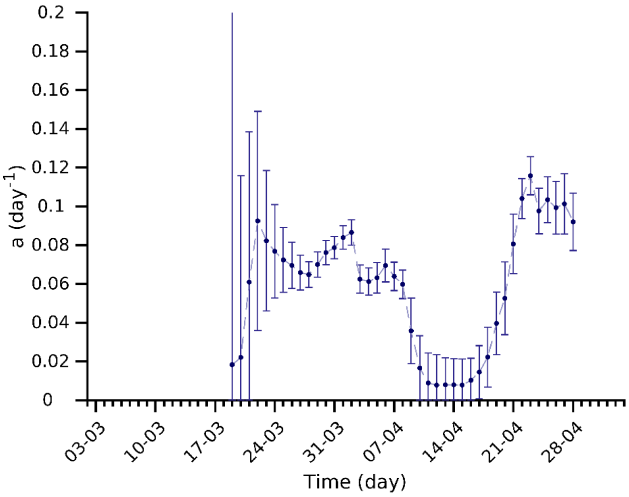


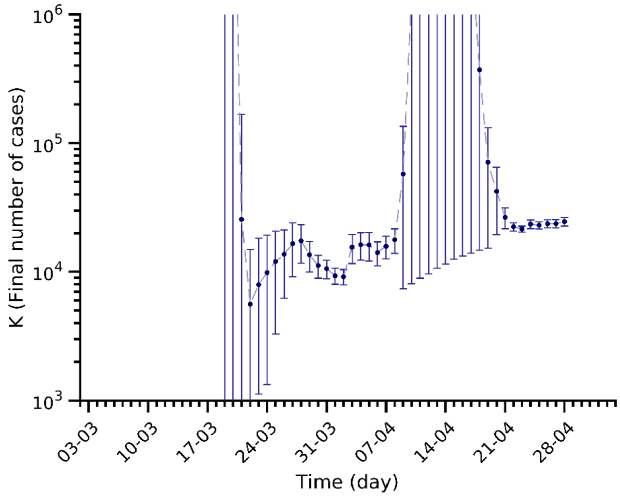


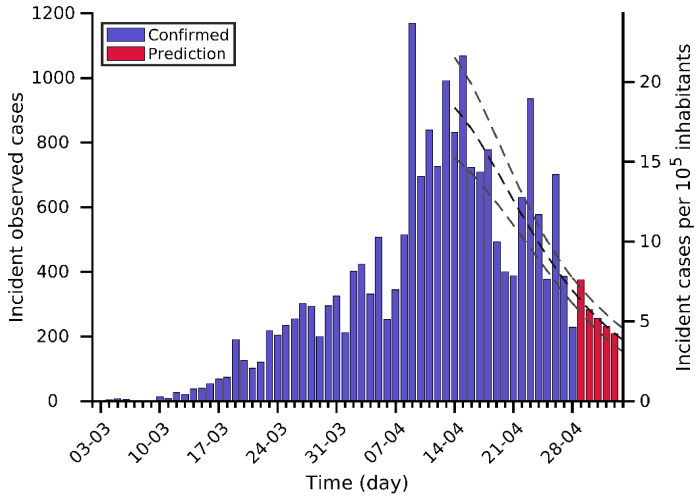
Ireland 28-04-2020. Population: 4.9M. Current cumulated incidence: 403/10^5

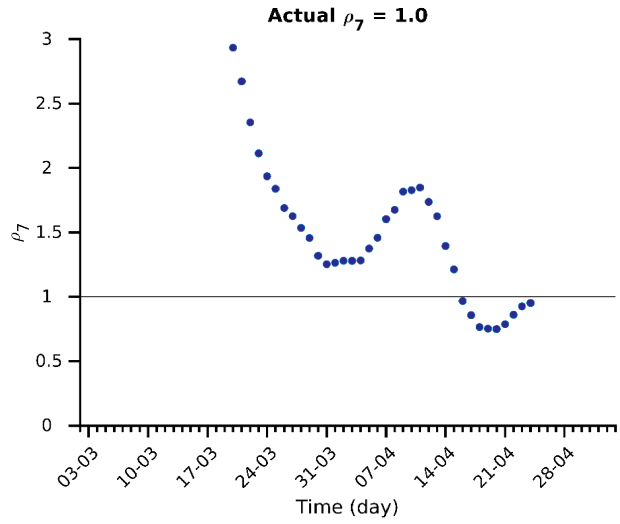


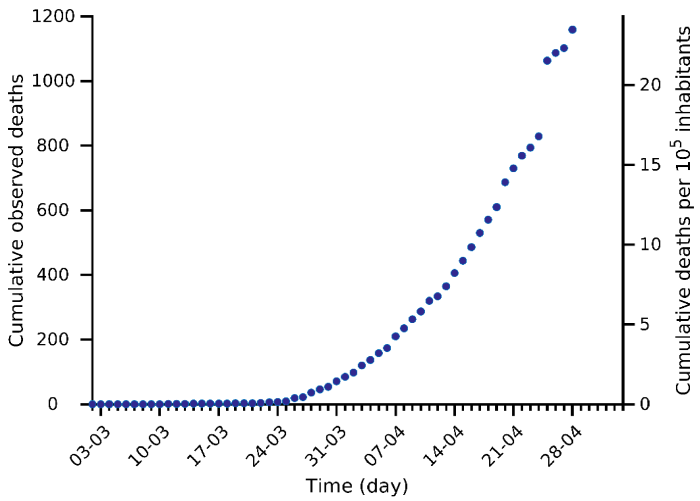


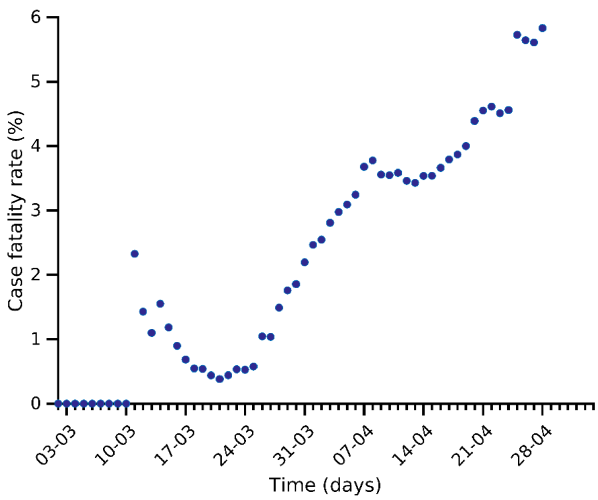




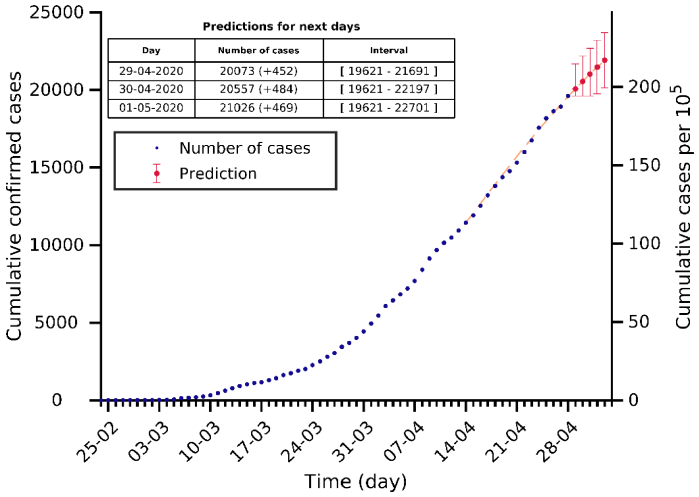


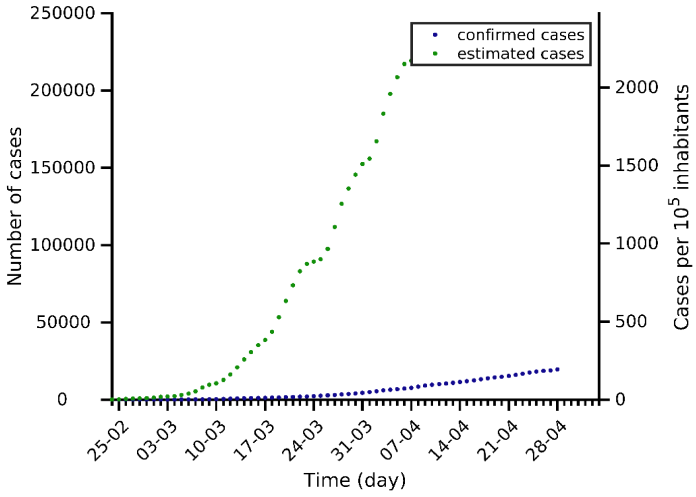


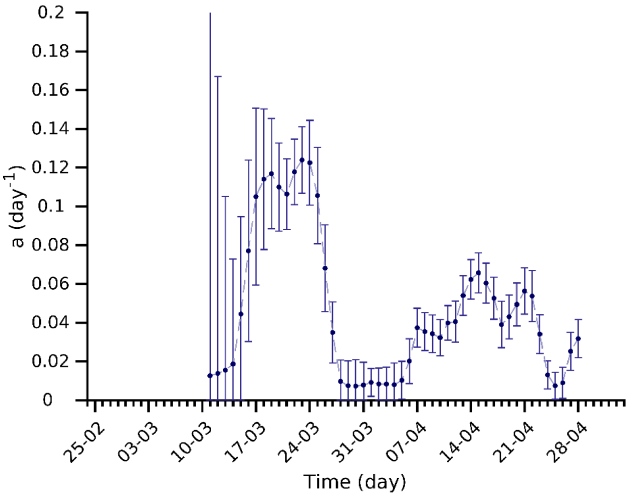


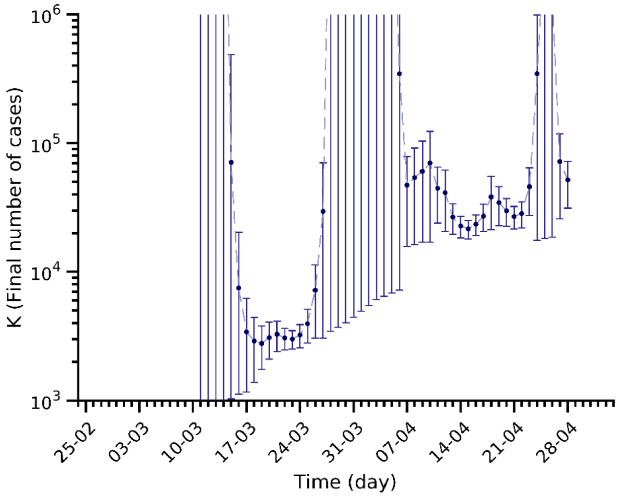


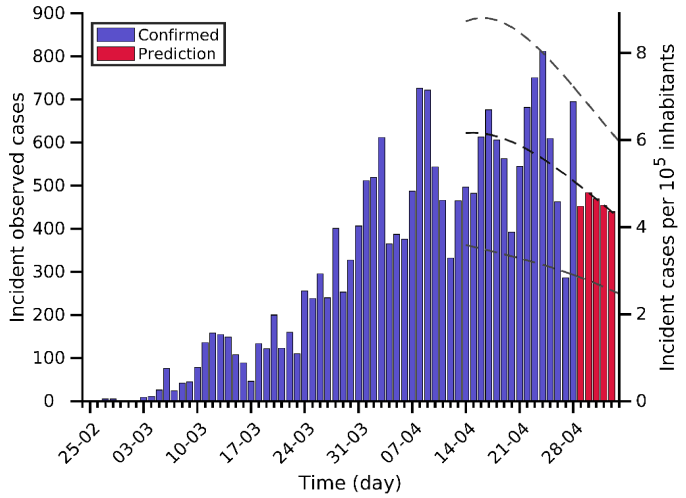
Sweden 28-04-2020. Population: 10.1M. Current cumulated incidence: 194/10⁵

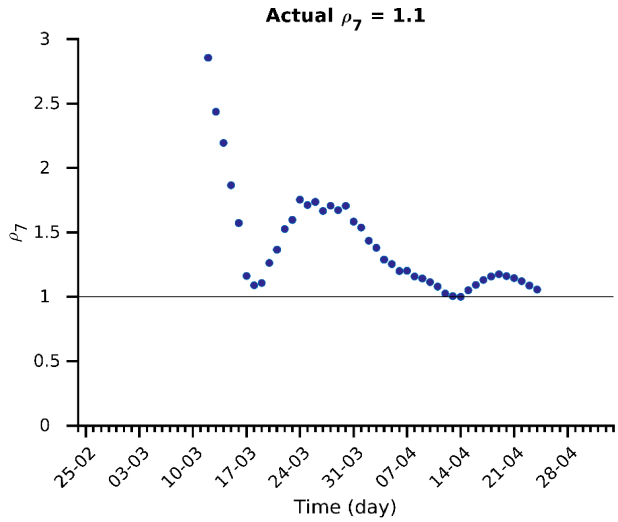


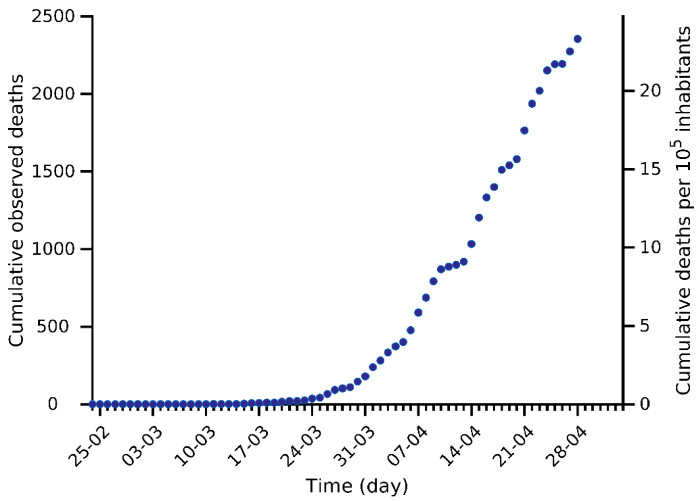


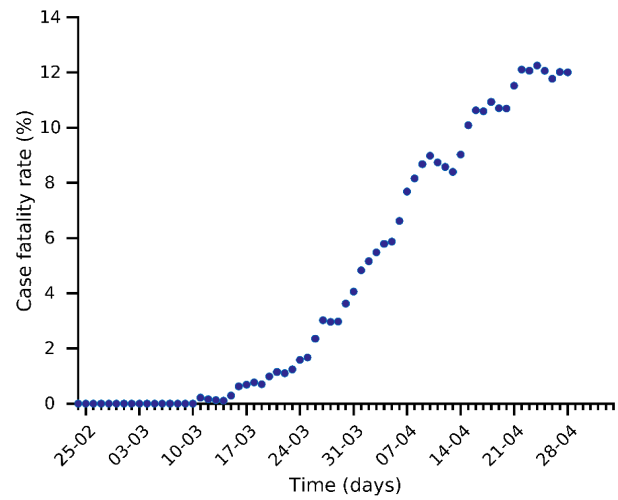




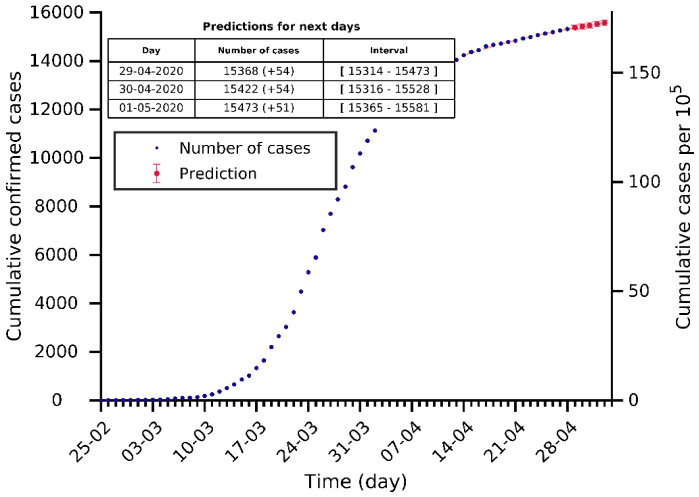


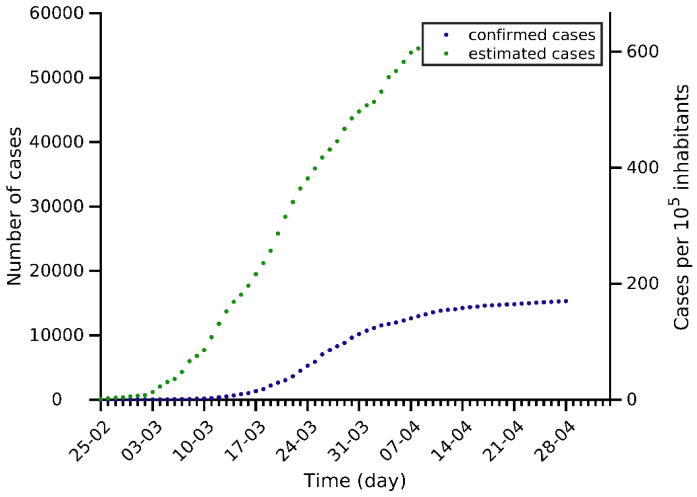


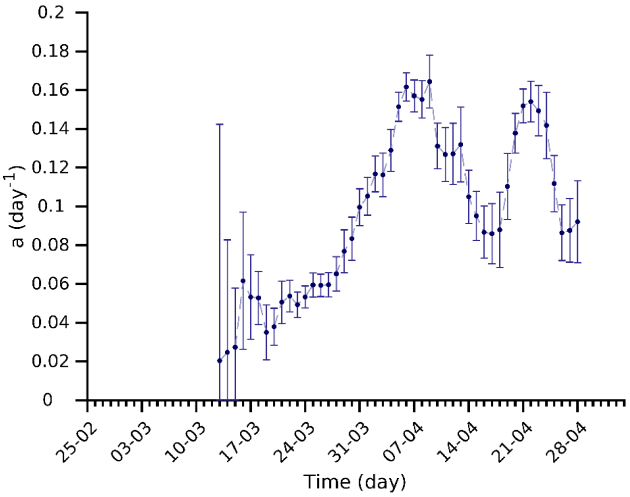


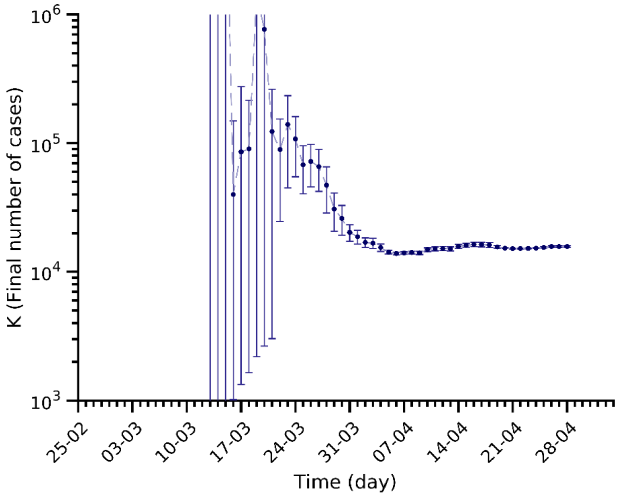


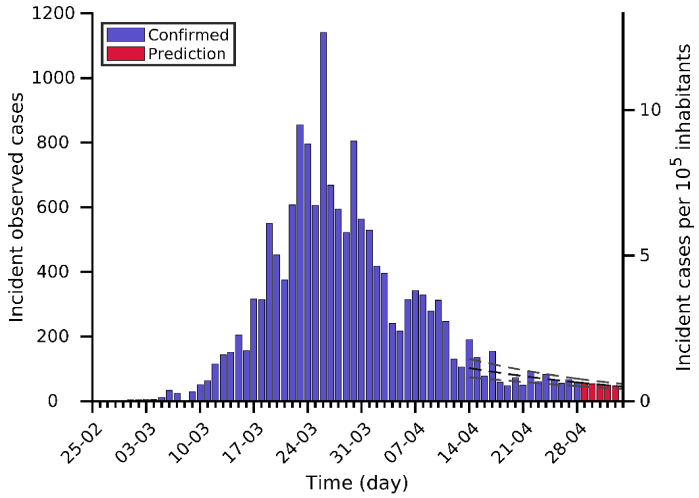
Austria 28-04-2020. Population: 9.0M. Current cumulated incidence: 170/10⁵

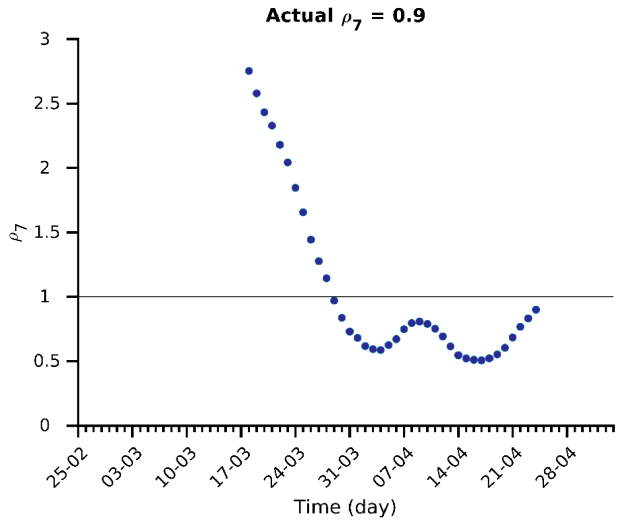


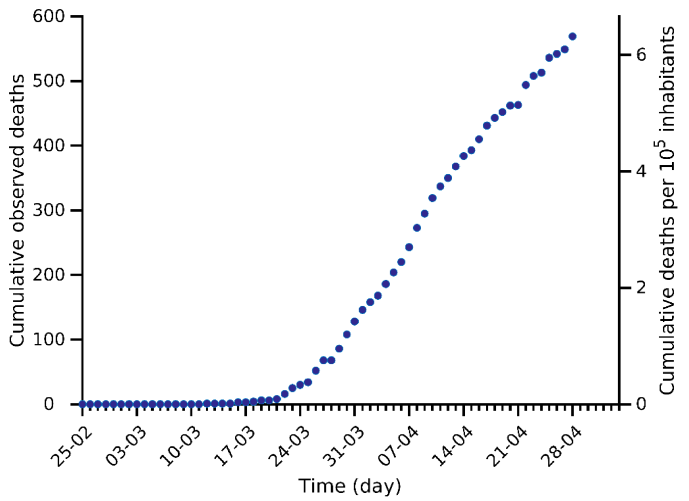


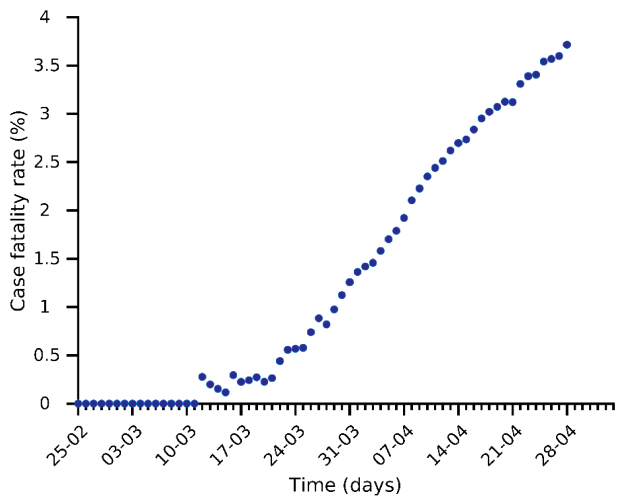




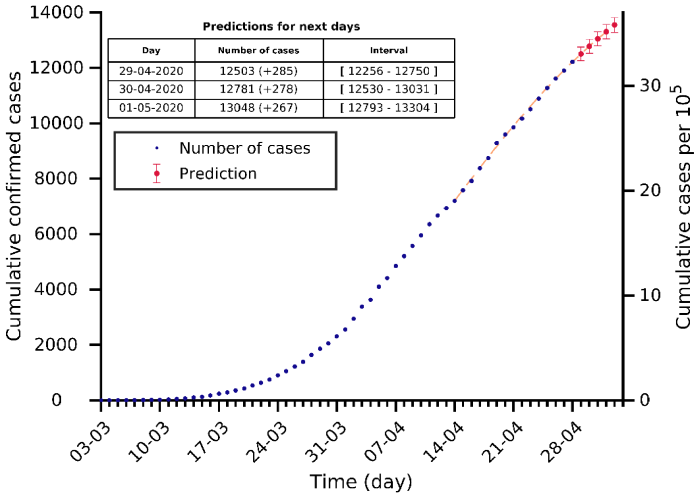


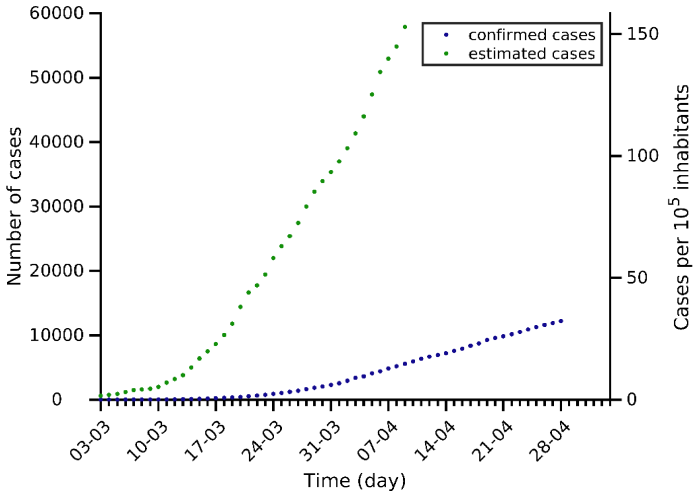


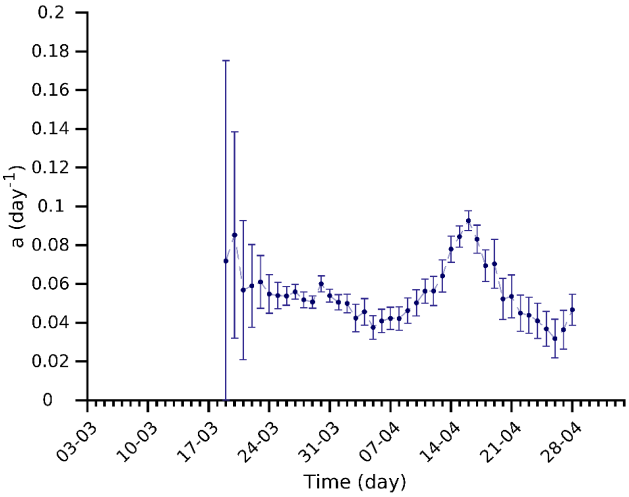


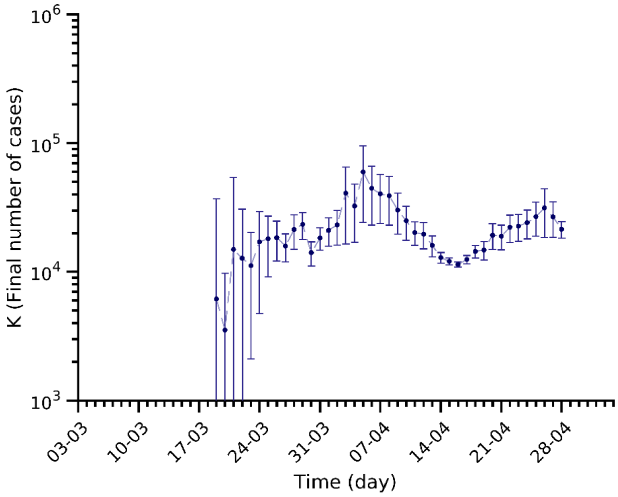


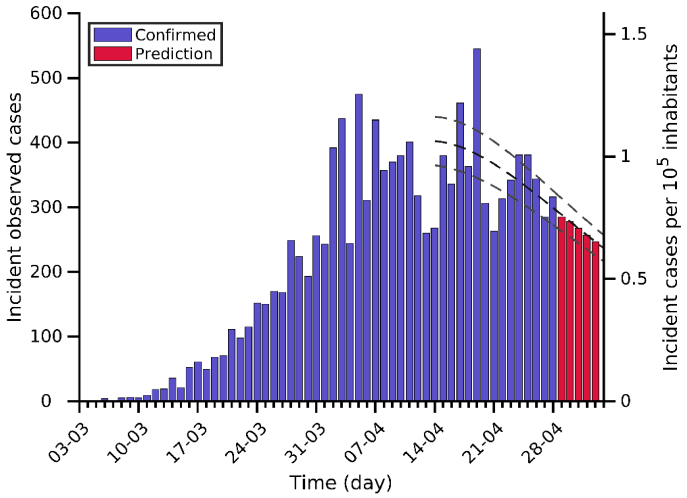
Poland 28-04-2020. Population: 37.8M. Current cumulated incidence: 32/10⁵

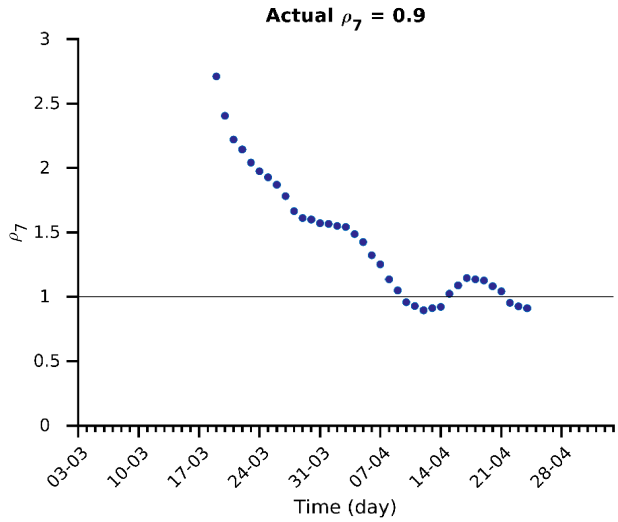


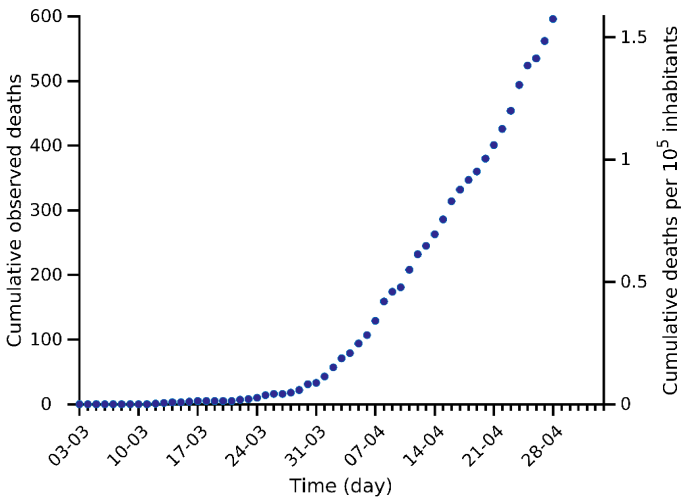


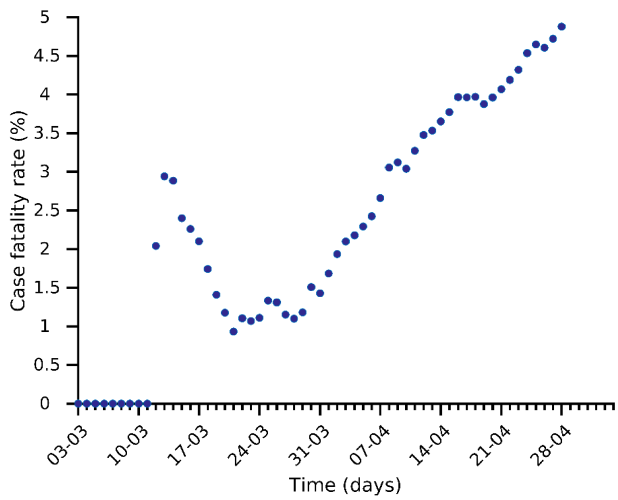




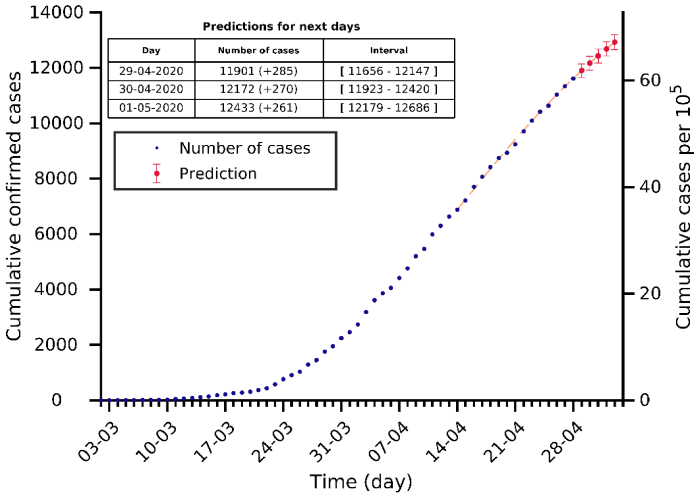


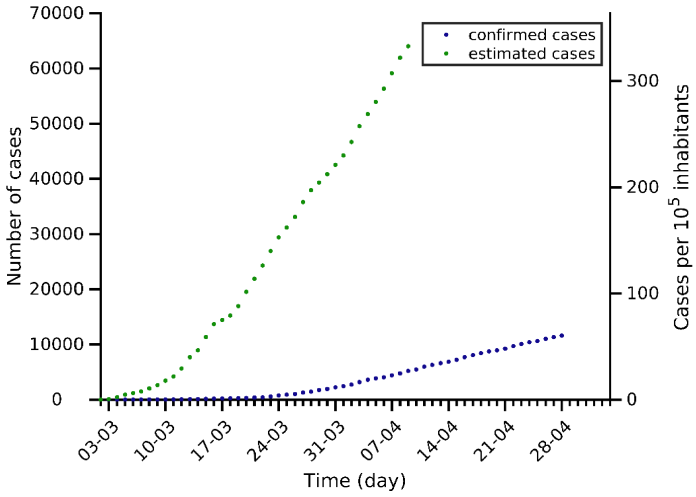


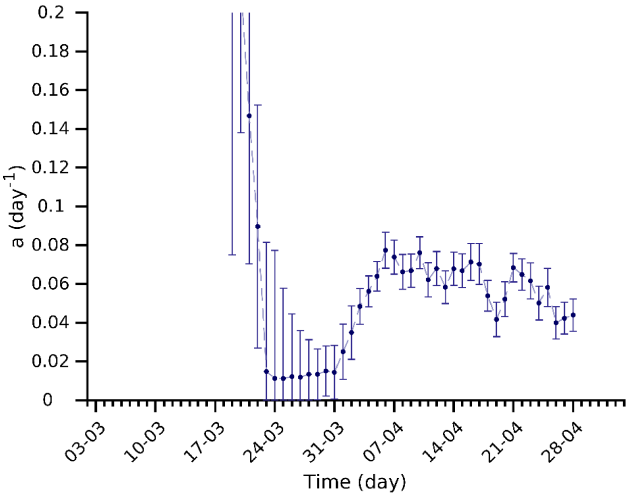


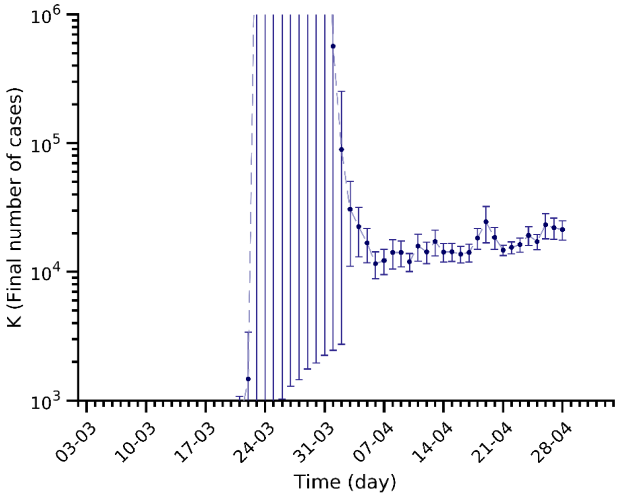


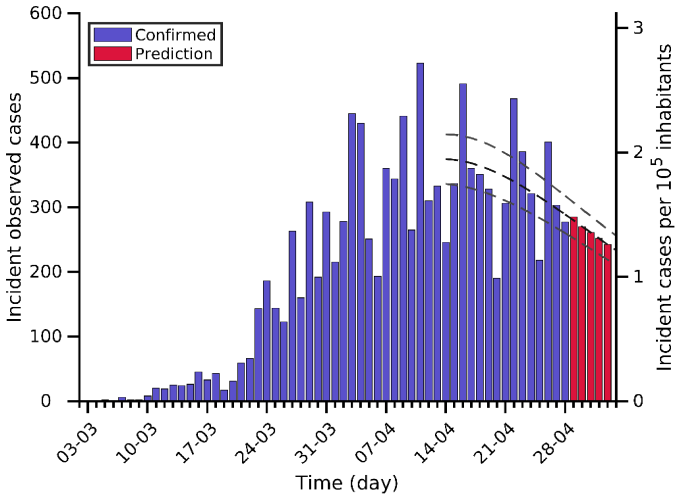
Romania 28-04-2020. Population: 19.2M. Current cumulated incidence: 60/10^5

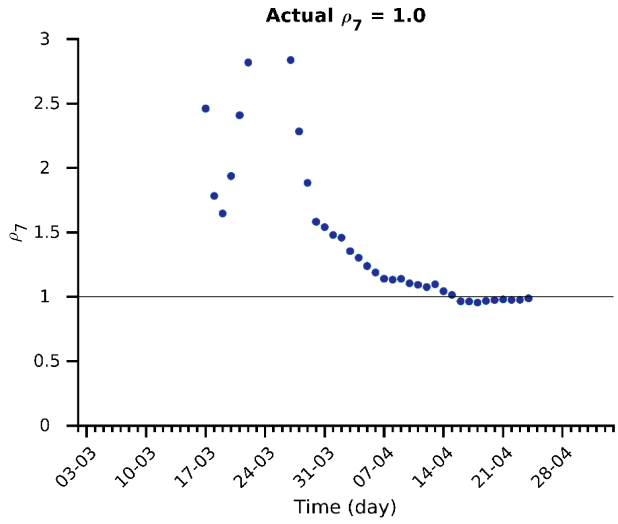


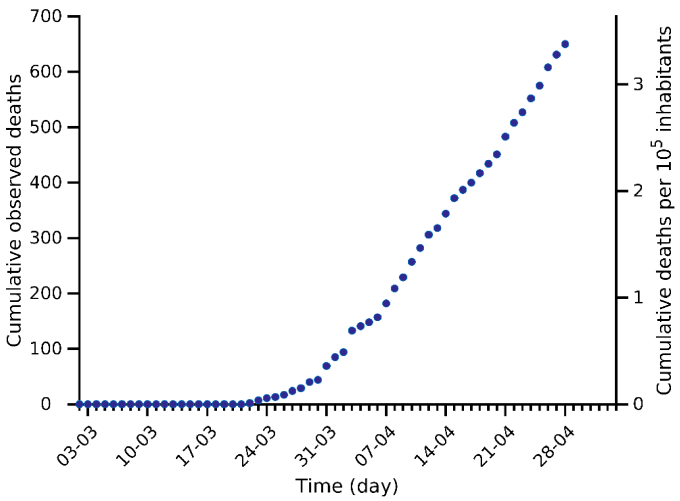


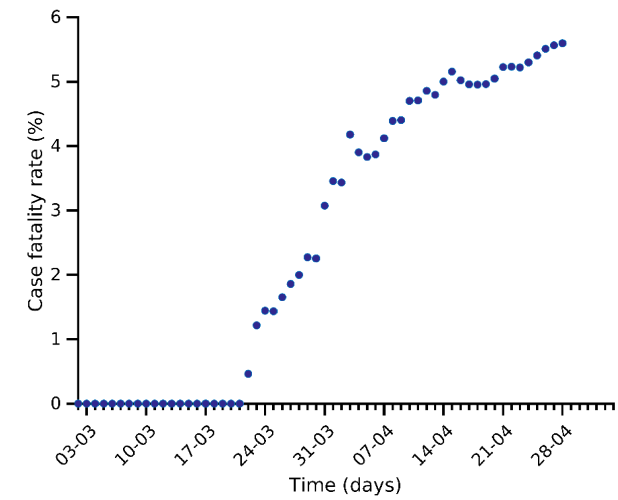




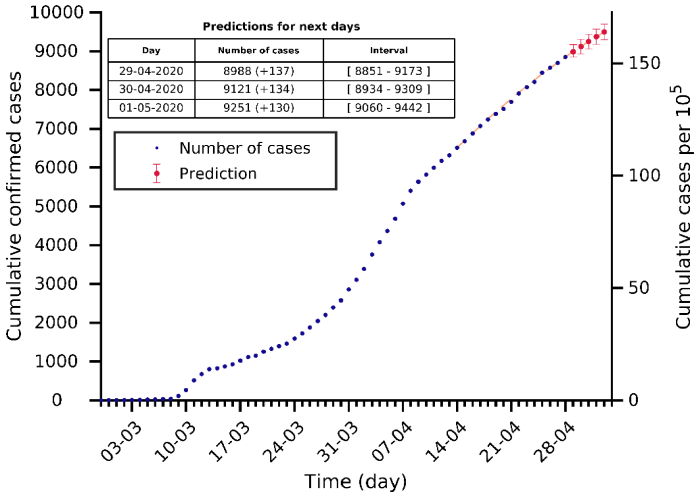


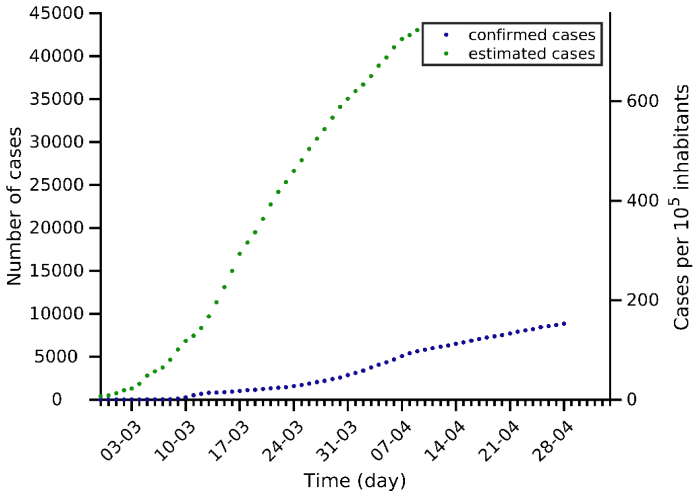


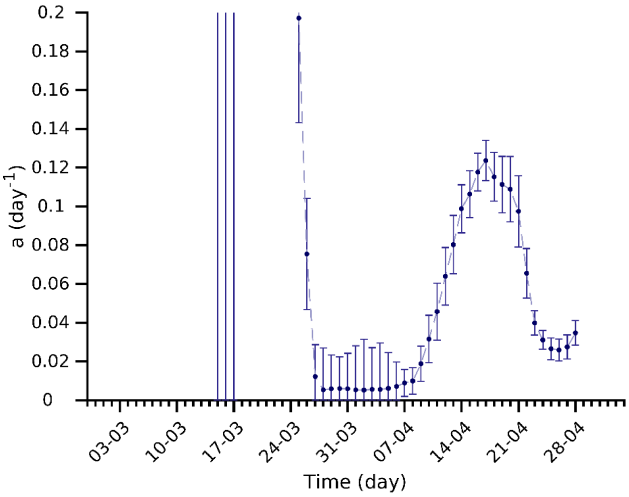


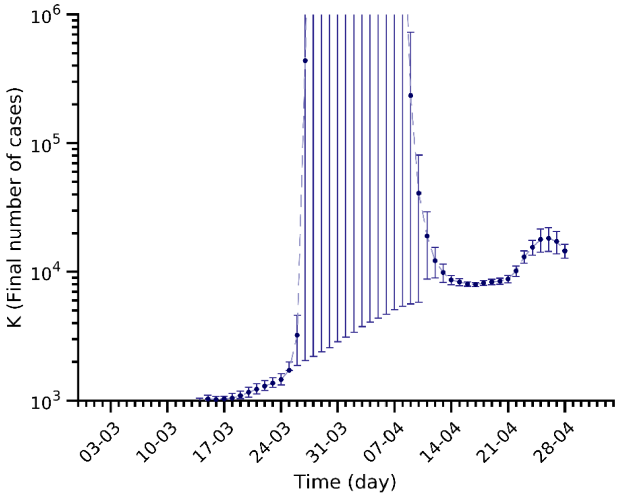


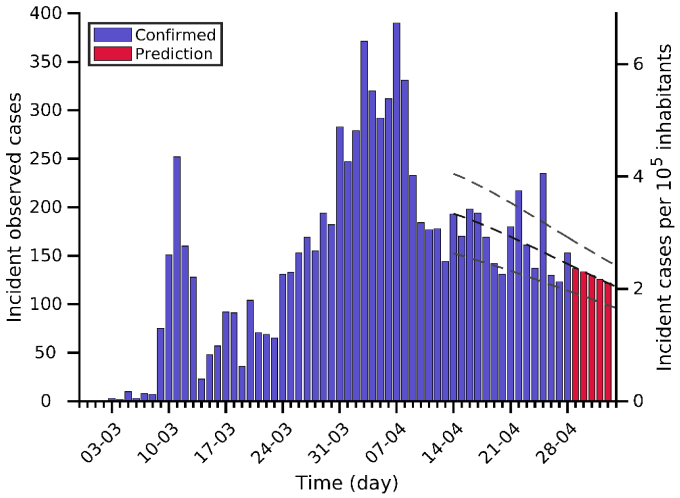
Denmark 28-04-2020. Population: 5.8M. Current cumulated incidence: $153/10^5$

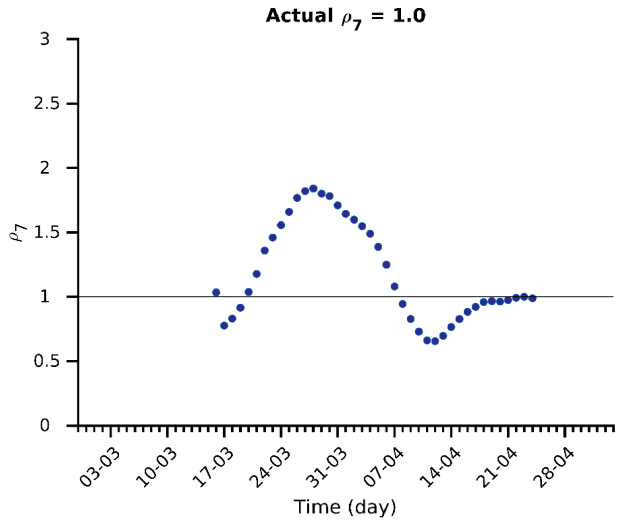


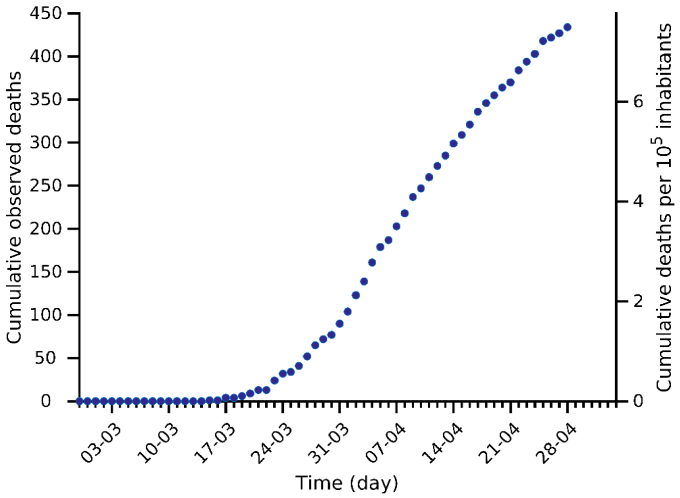


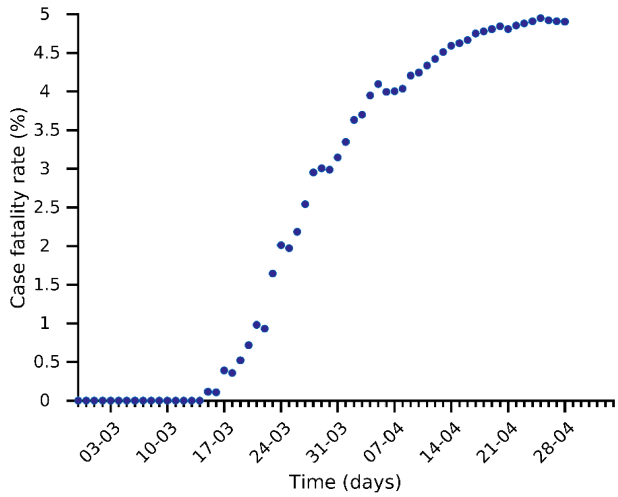




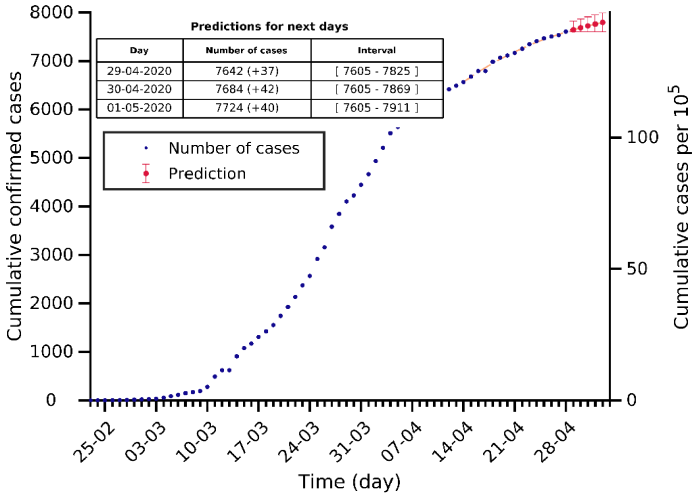


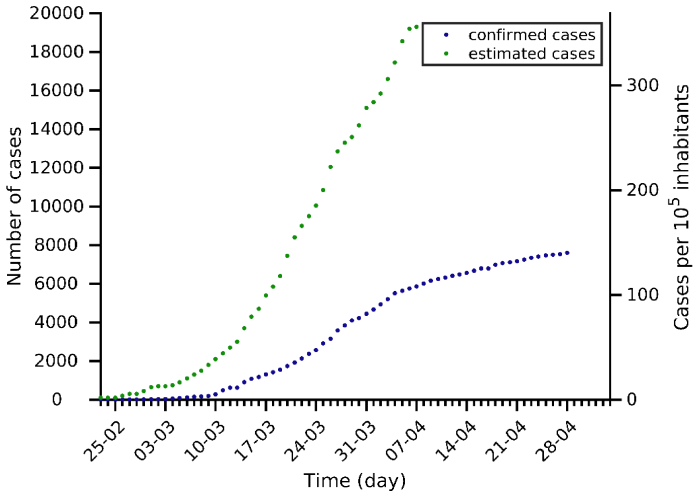


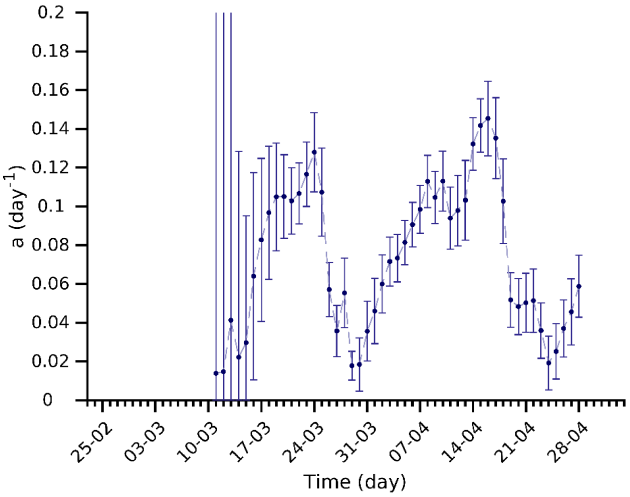


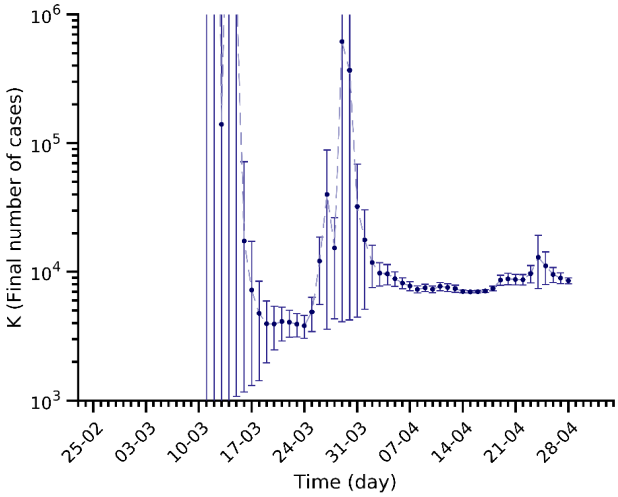


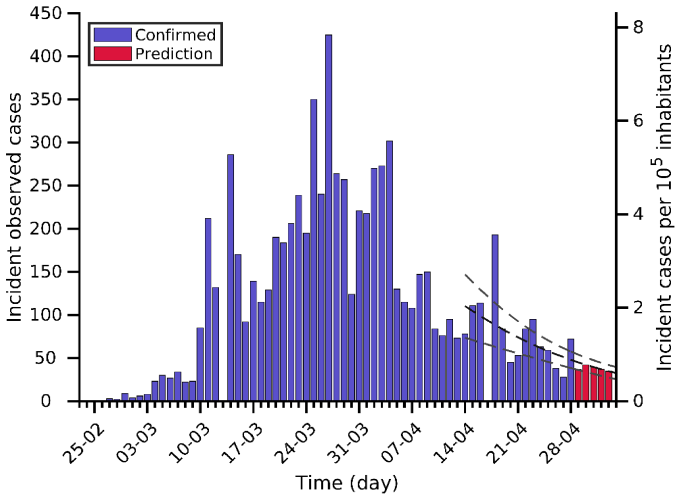
Norway 28-04-2020. Population: 5.4M. Current cumulated incidence: 140/10⁵

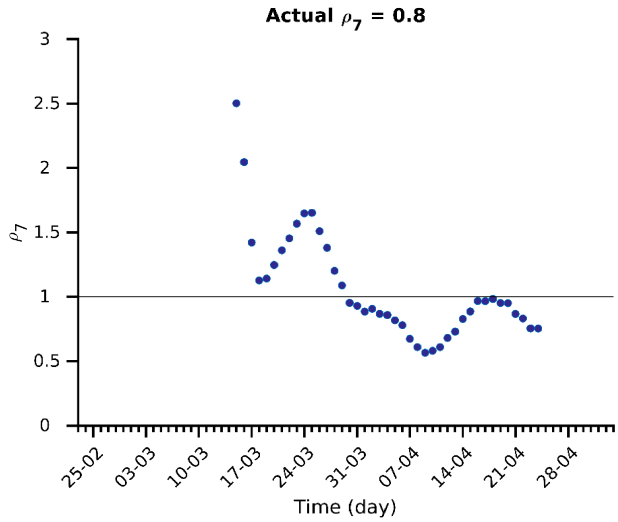


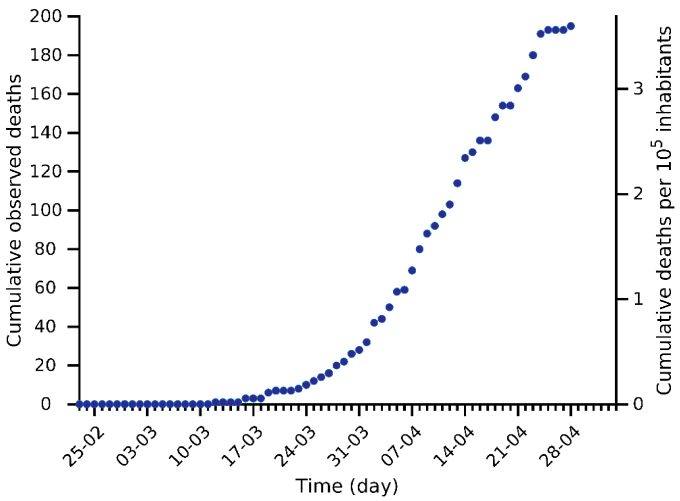


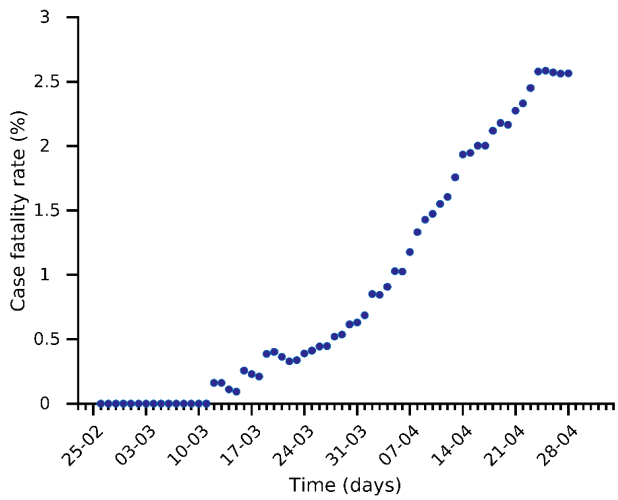




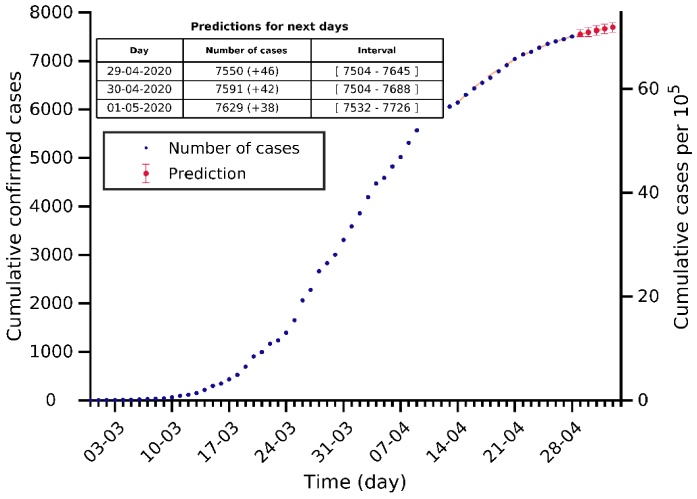


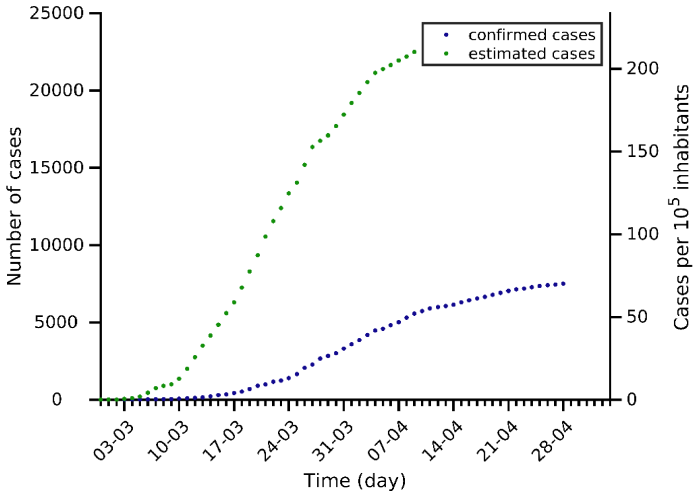


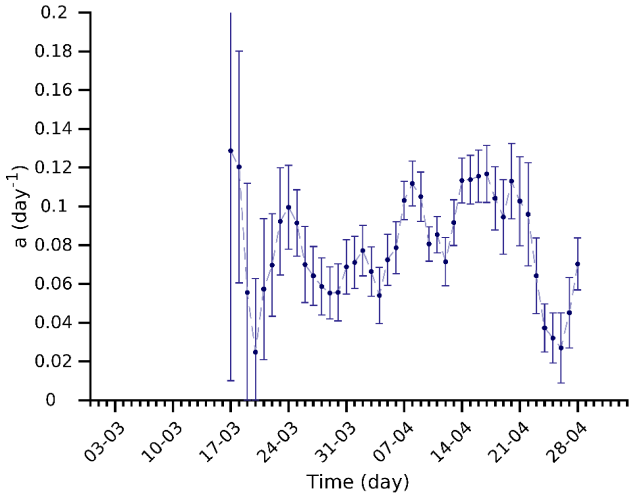


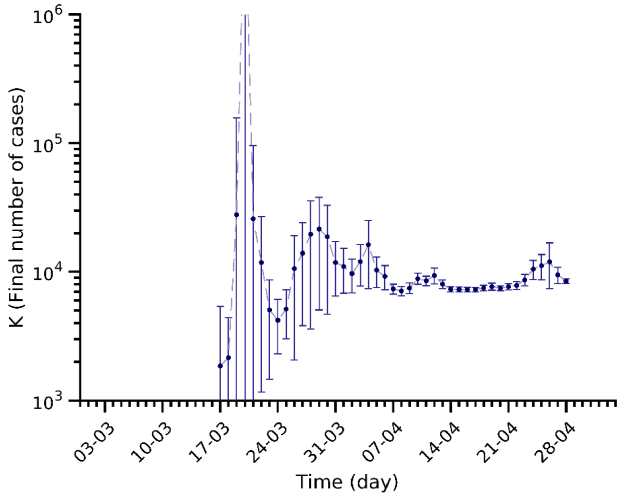


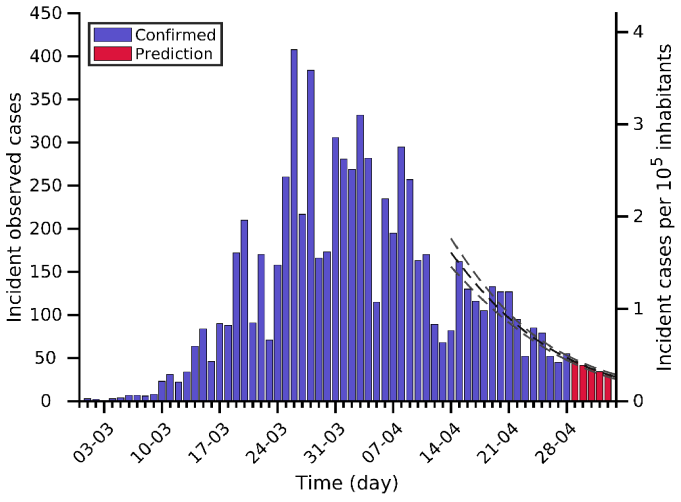
Czech Rep 28-04-2020. Population: 10.7M. Current cumulated incidence: 70/10^5

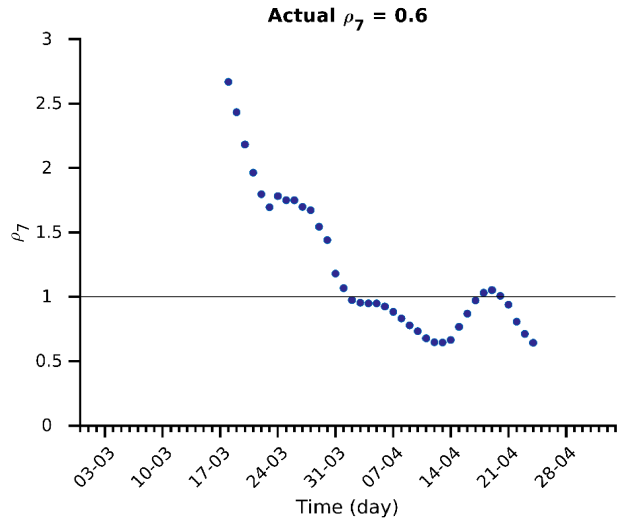


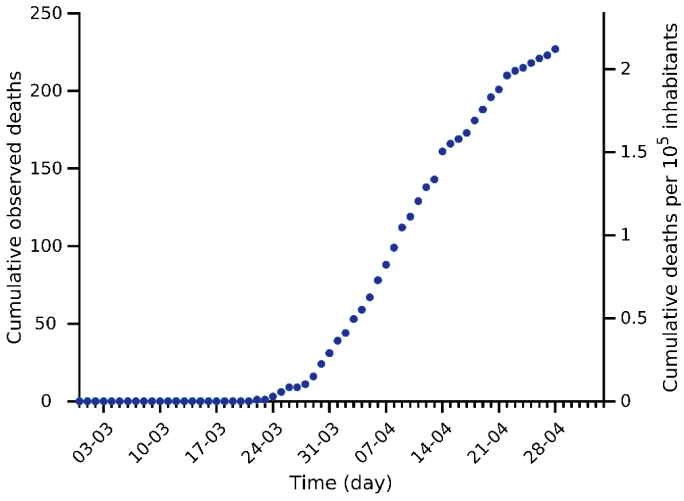


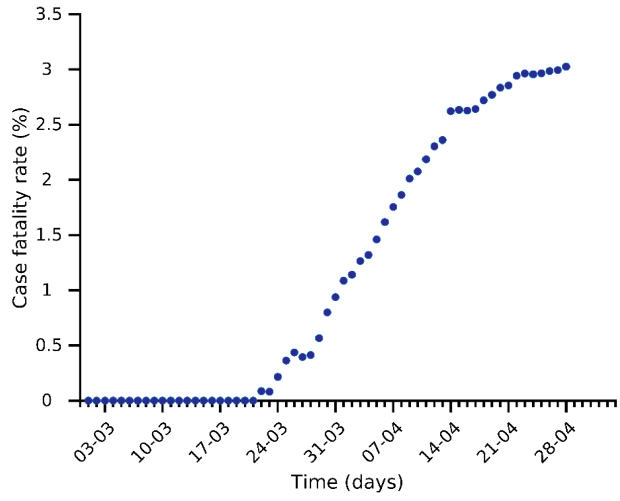




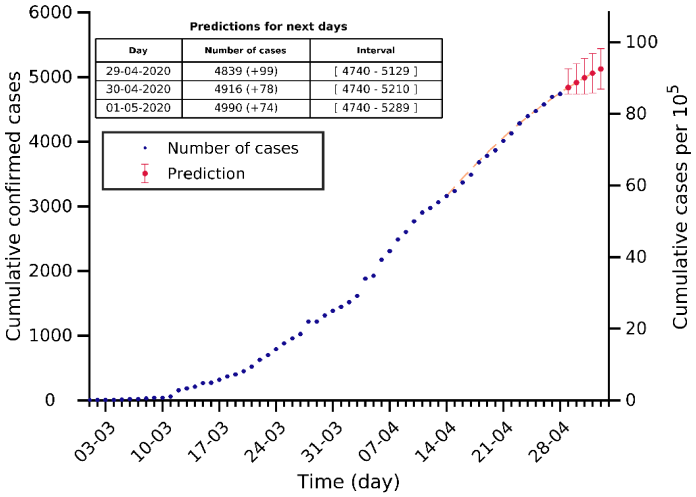


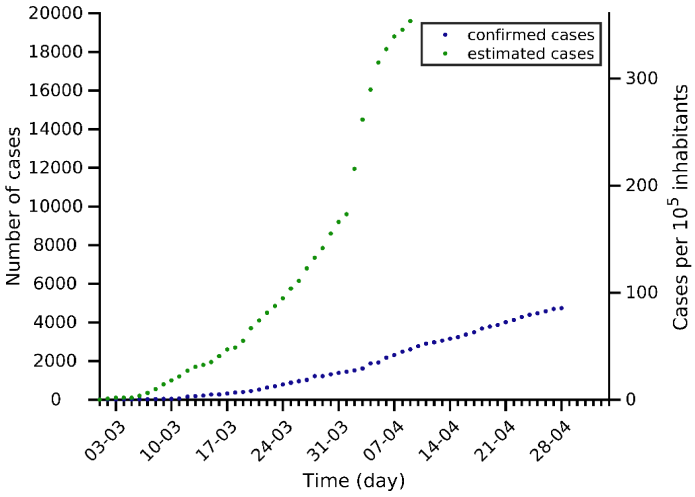


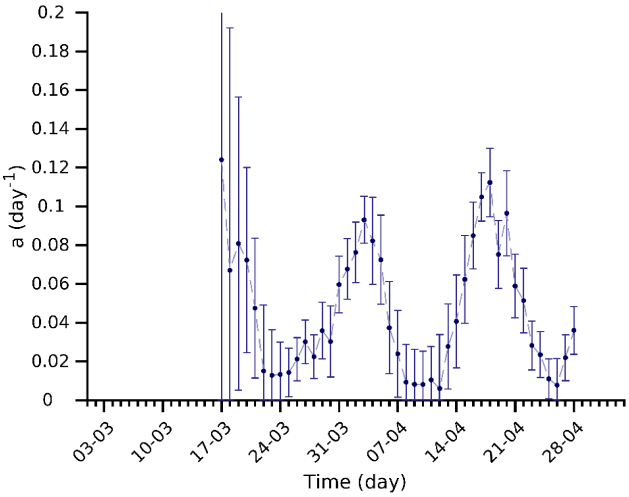


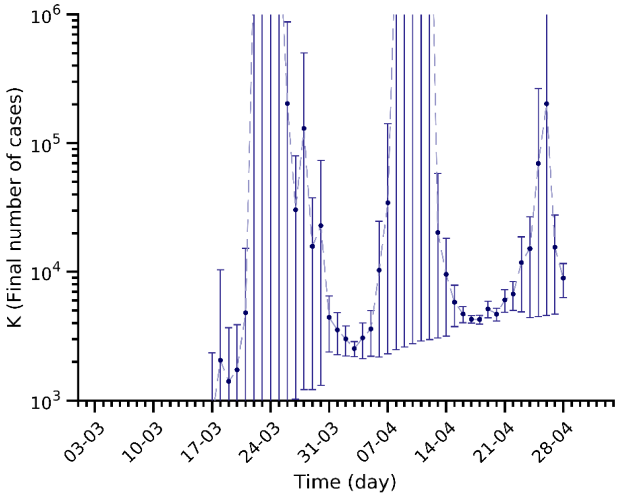


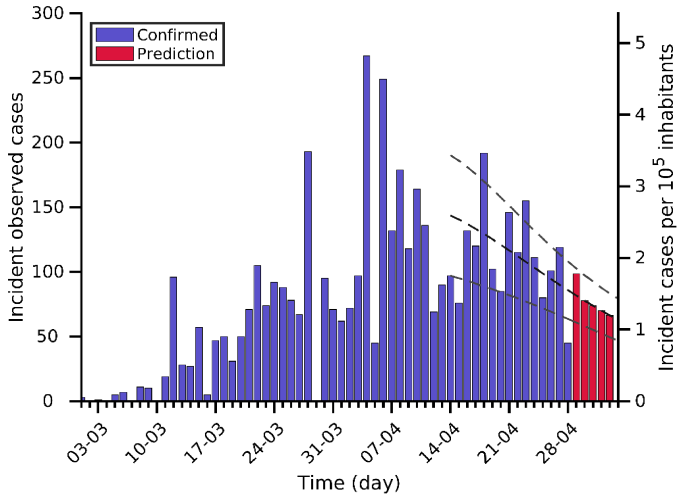
Finland 28-04-2020. Population: 5.5M. Current cumulated incidence: 86/10^5

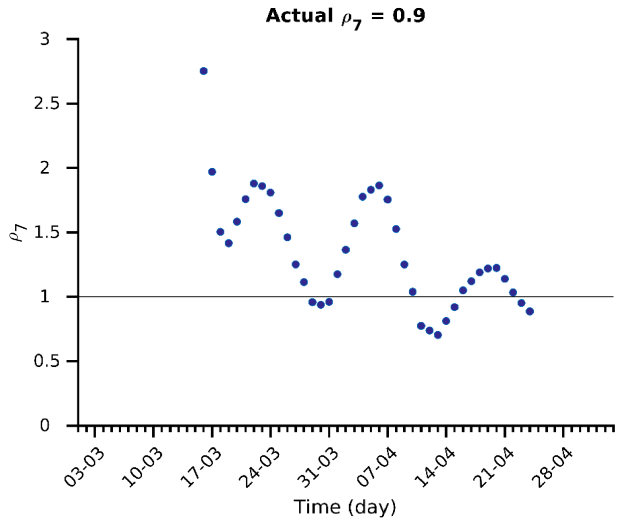


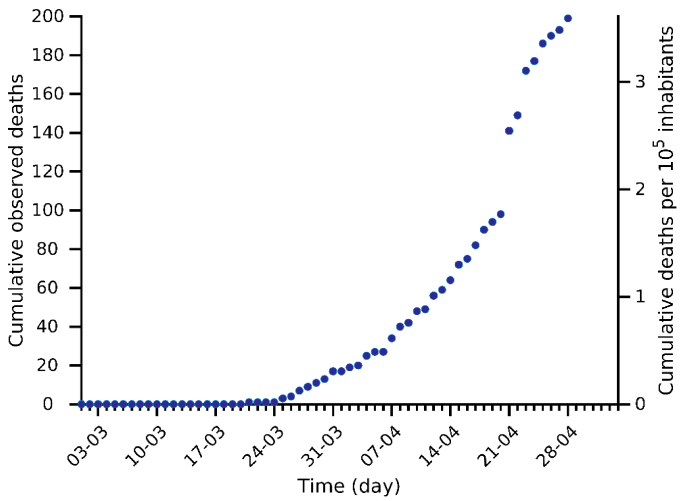


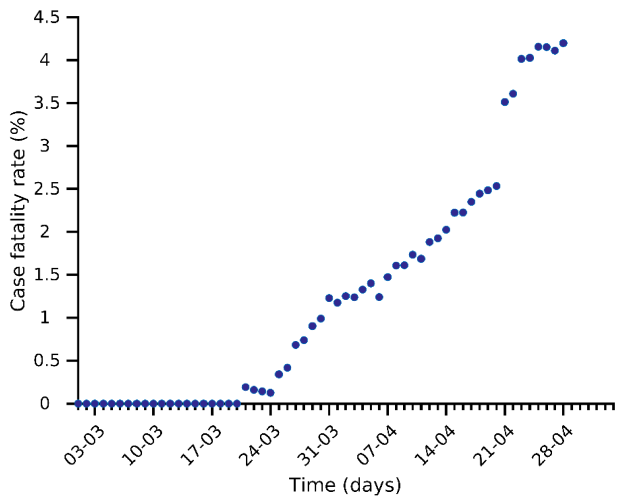




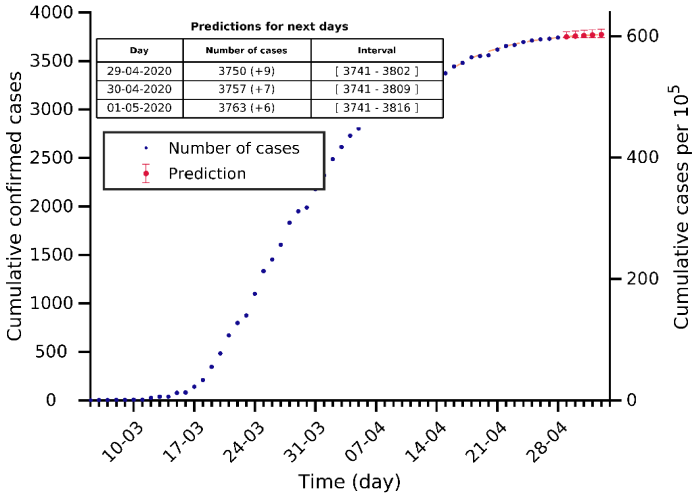


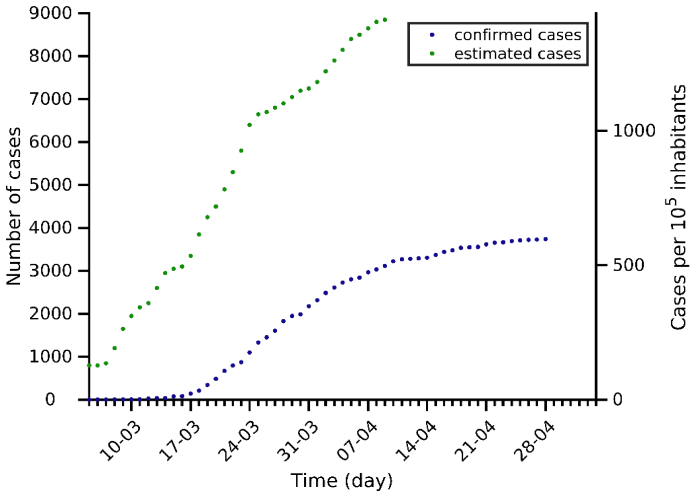


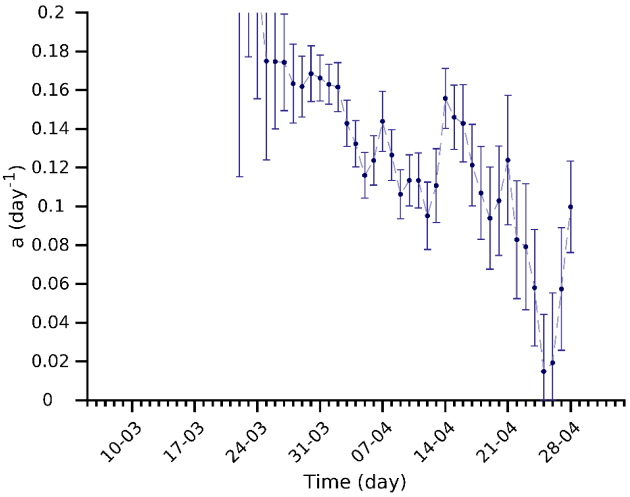


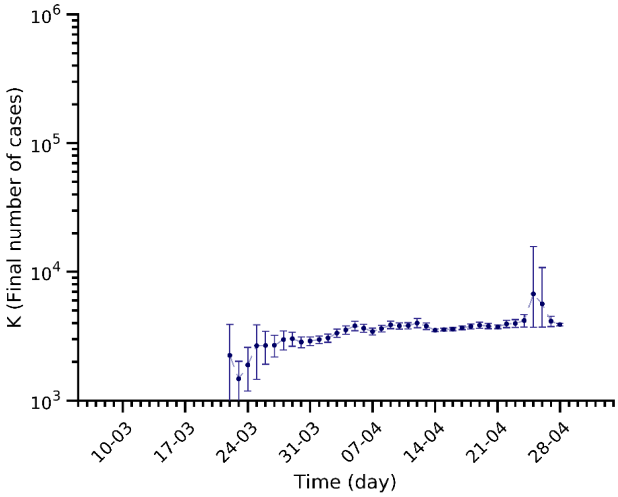


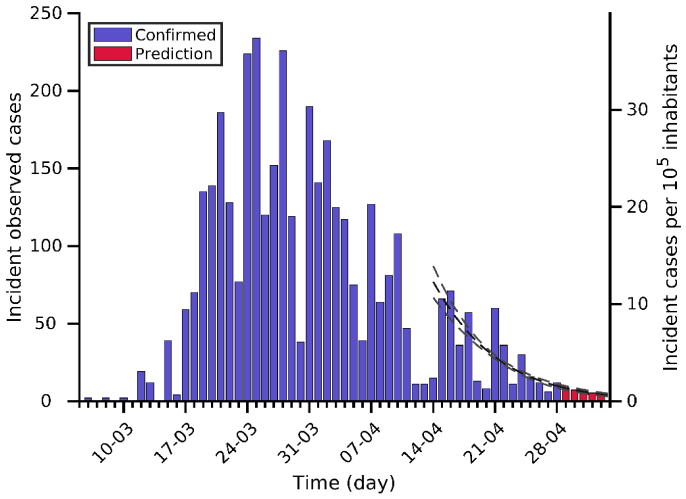
Luxembourg 28-04-2020. Population: 0.6M. Current cumulated incidence: 598/10^5

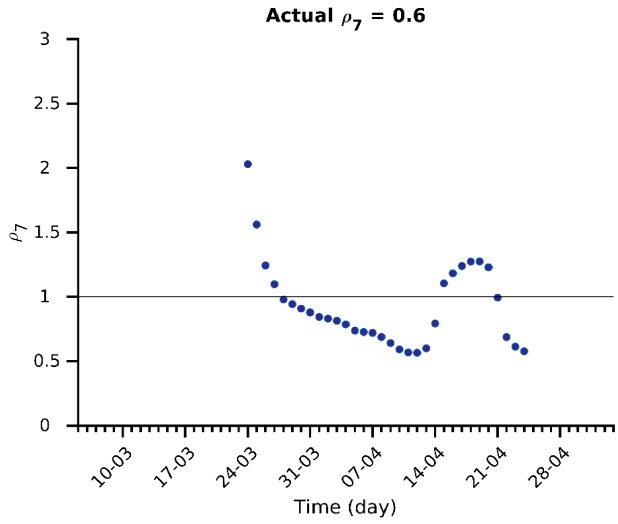


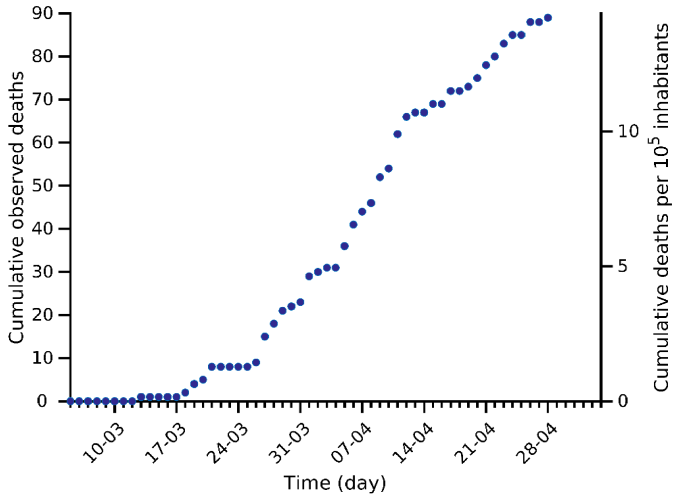


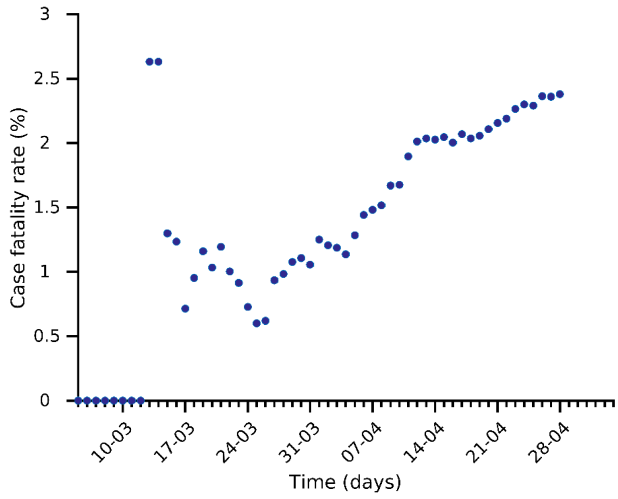




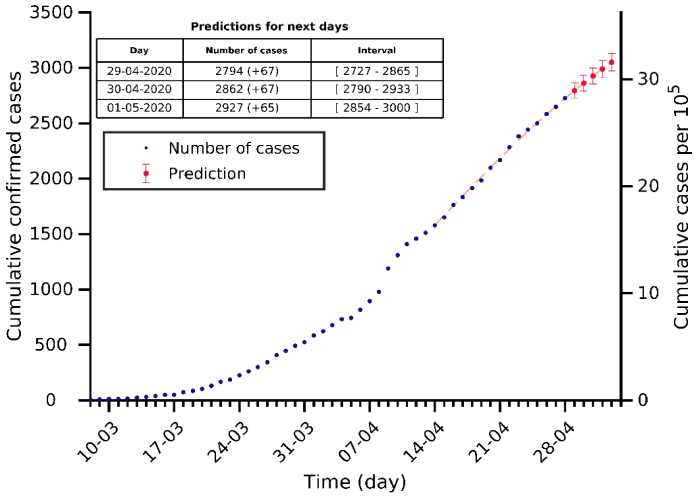


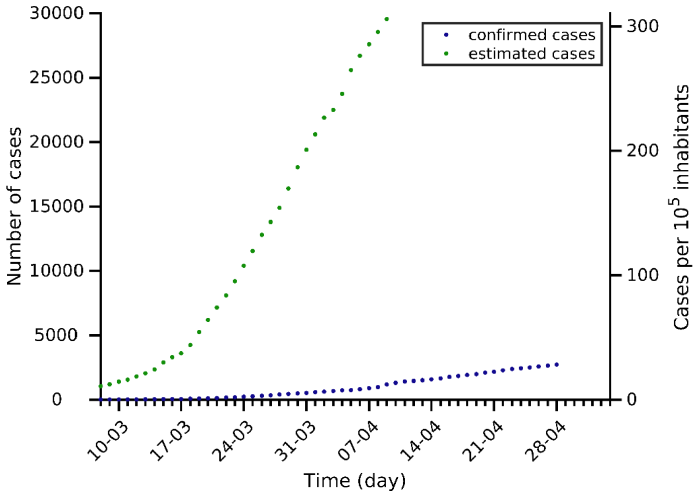


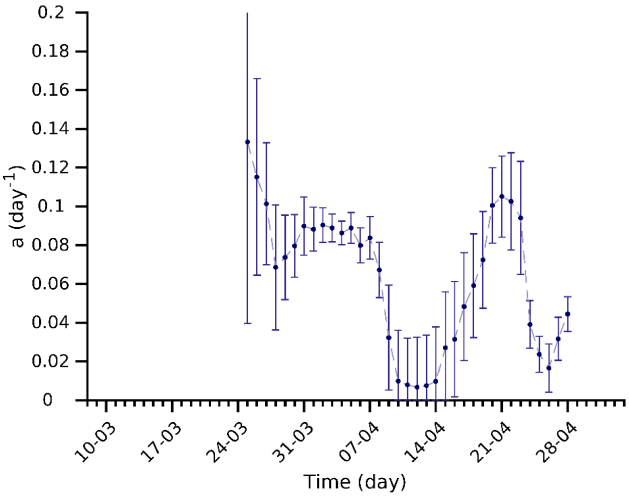


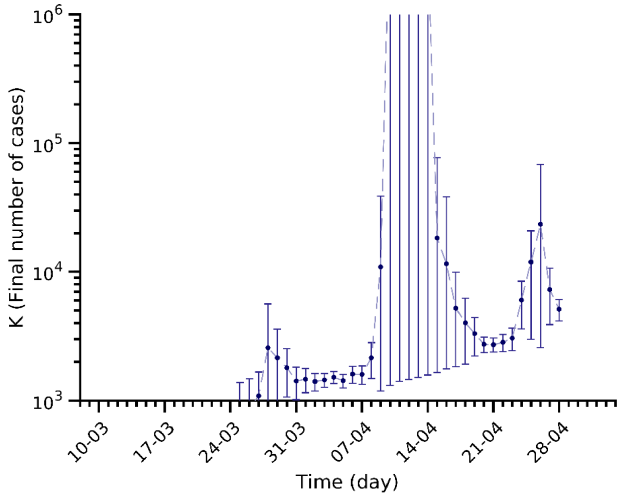


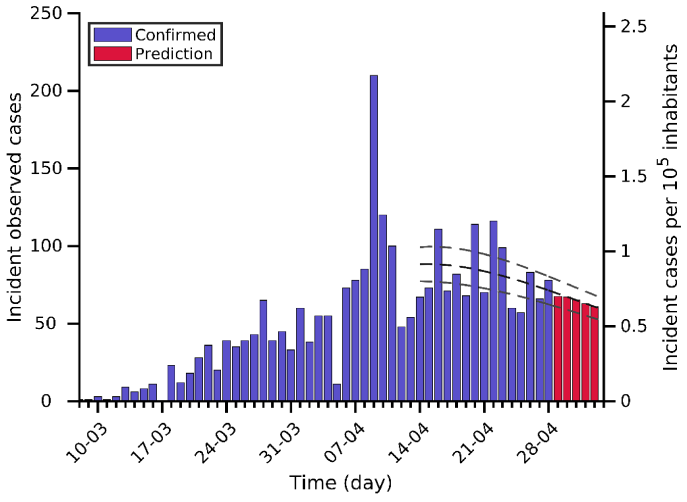
Hungary 28-04-2020. Population: 9.7M. Current cumulated incidence: $28/10^5$

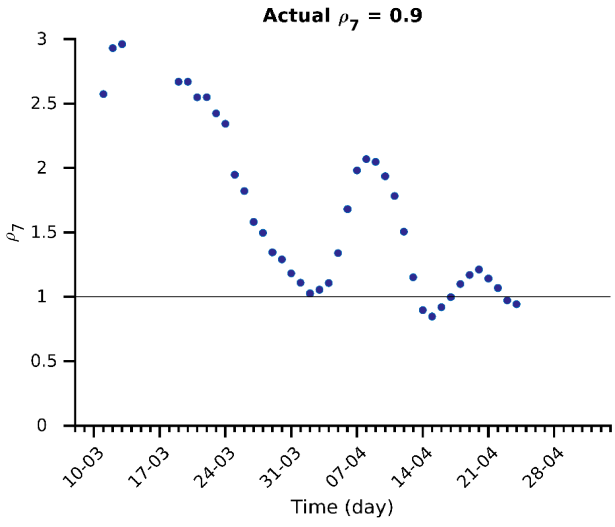


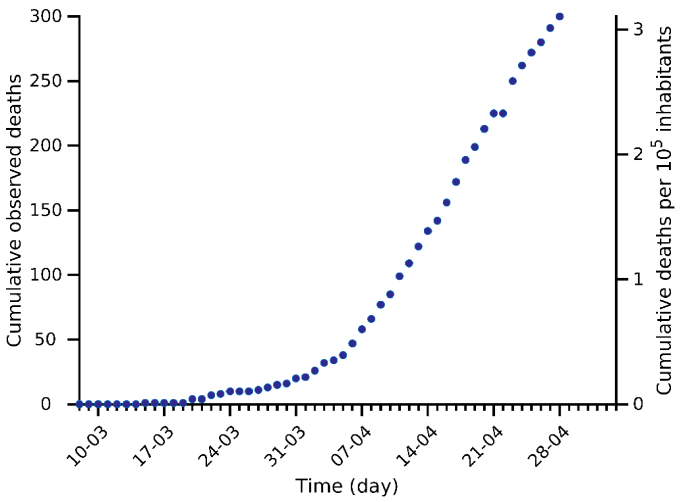


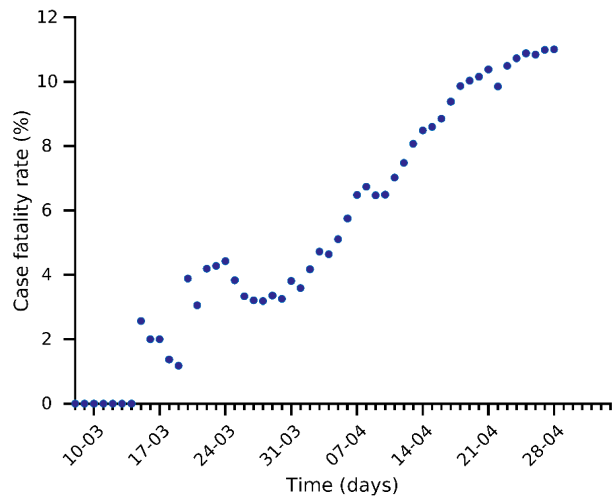




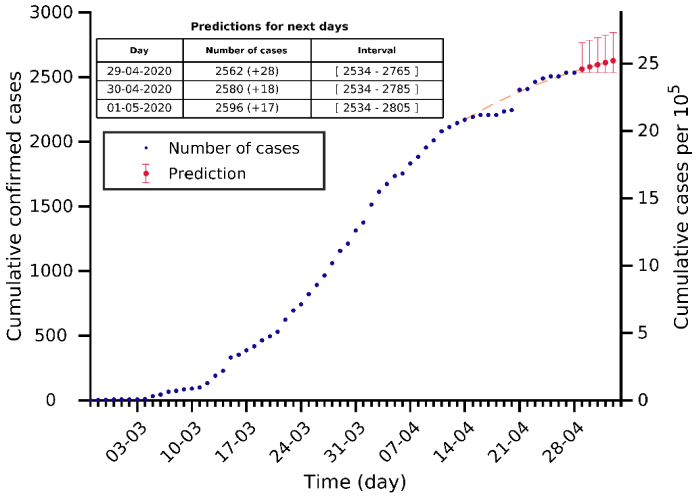


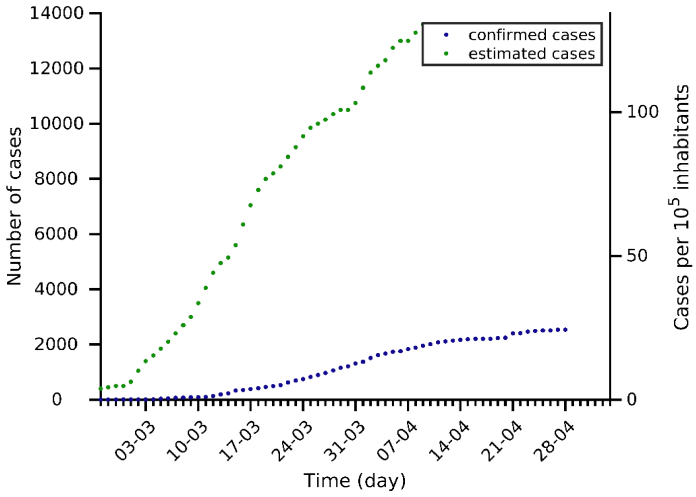


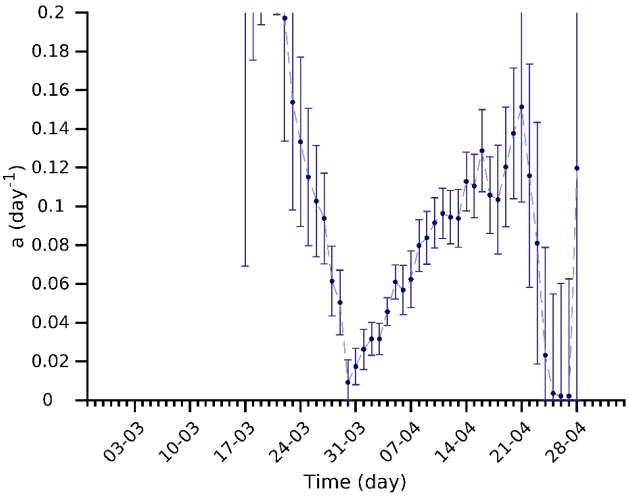


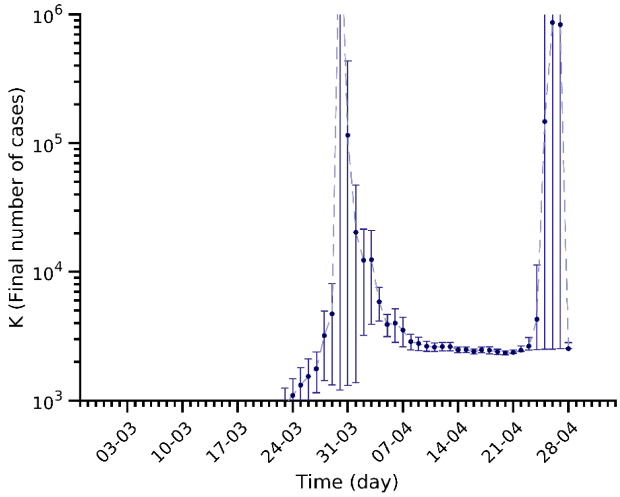


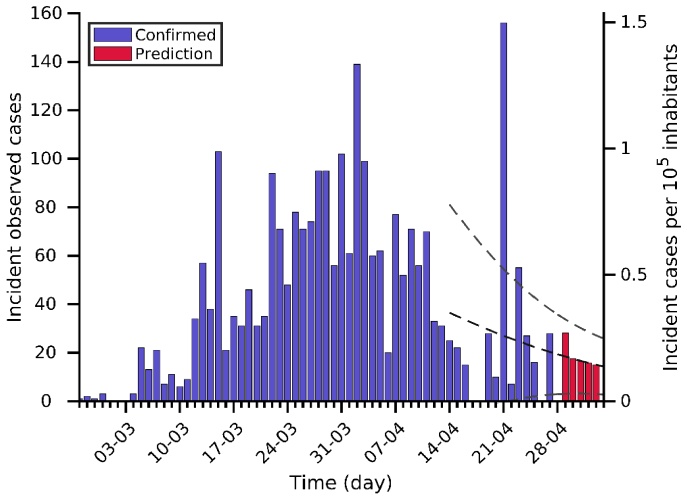
Greece 28-04-2020. Population: 10.4M. Current cumulated incidence: 24/10^5

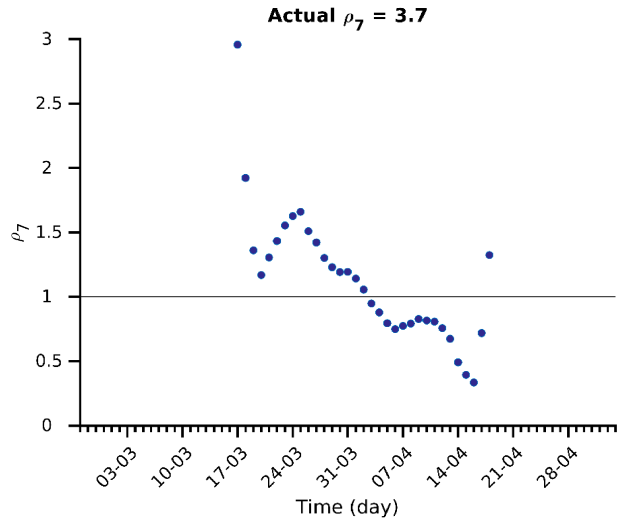


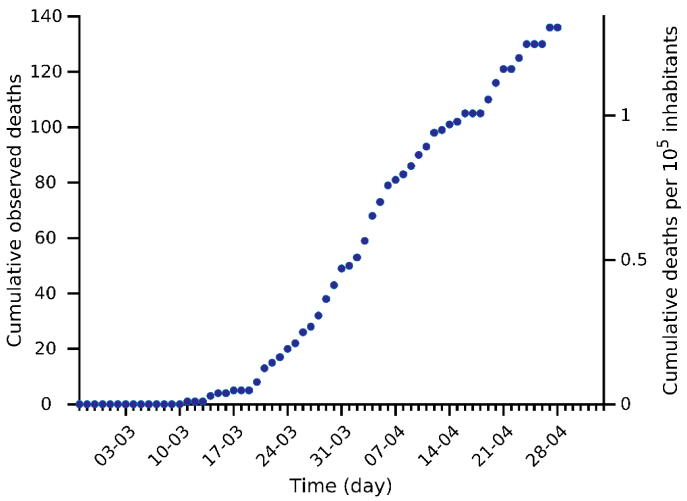


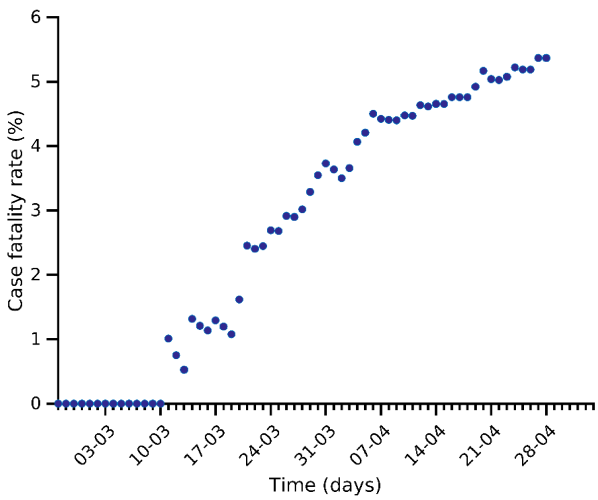




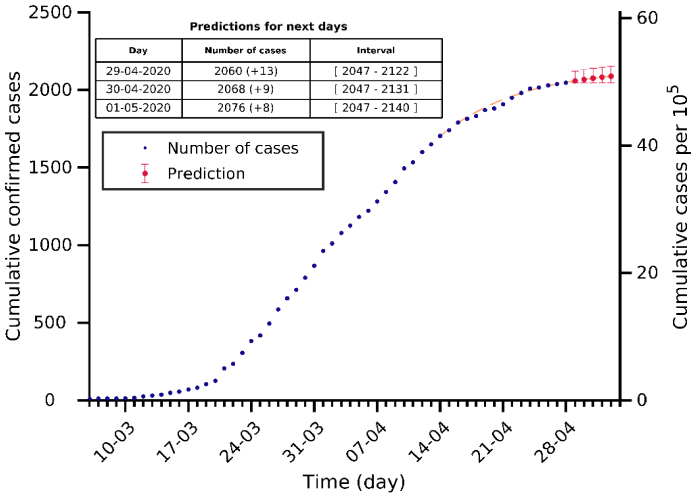


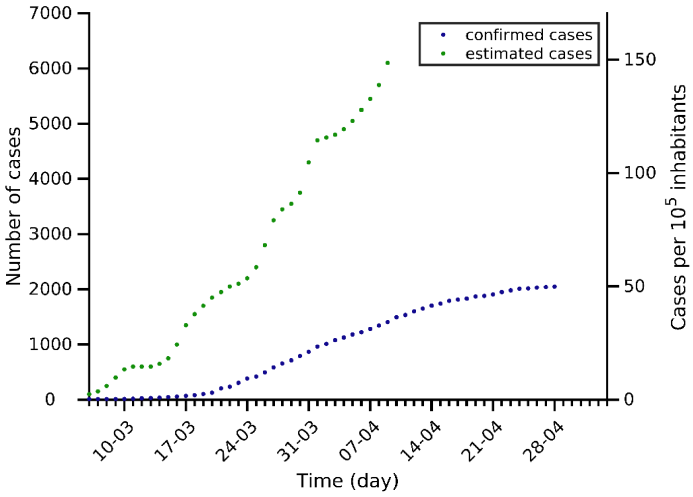


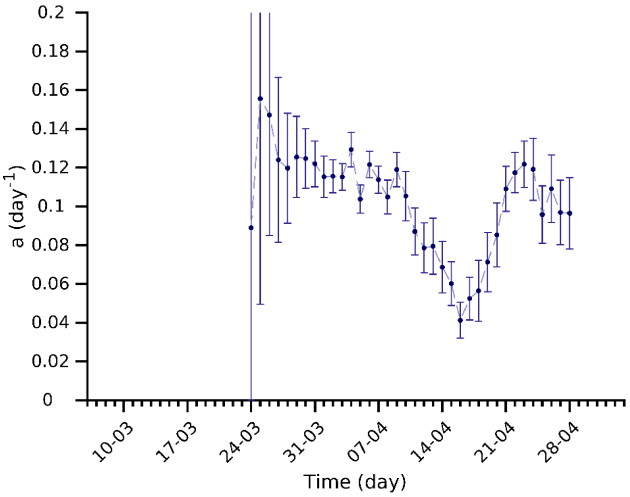


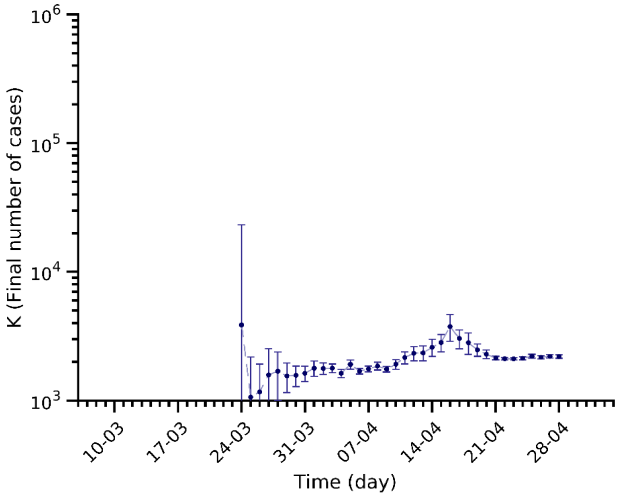


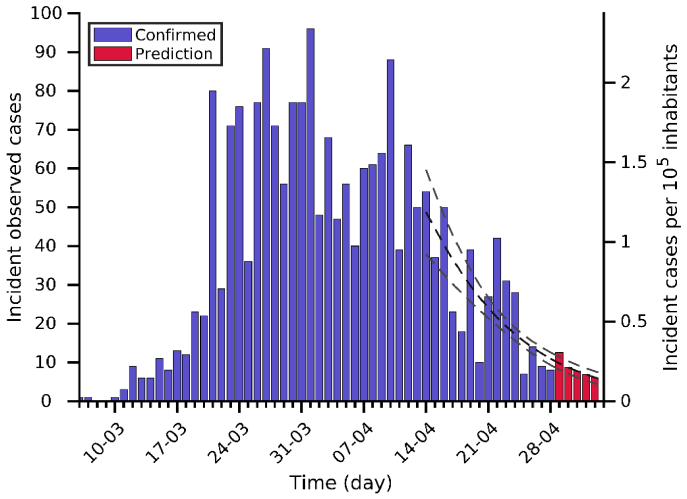
Croatia 28-04-2020. Population: 4.1M. Current cumulated incidence: $50/10^5$

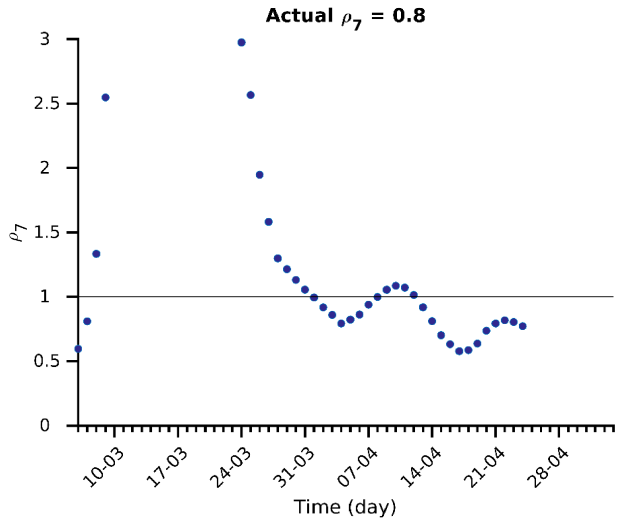


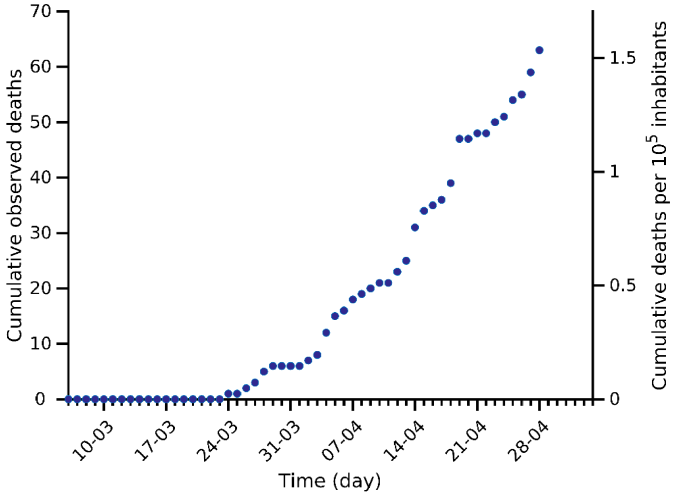


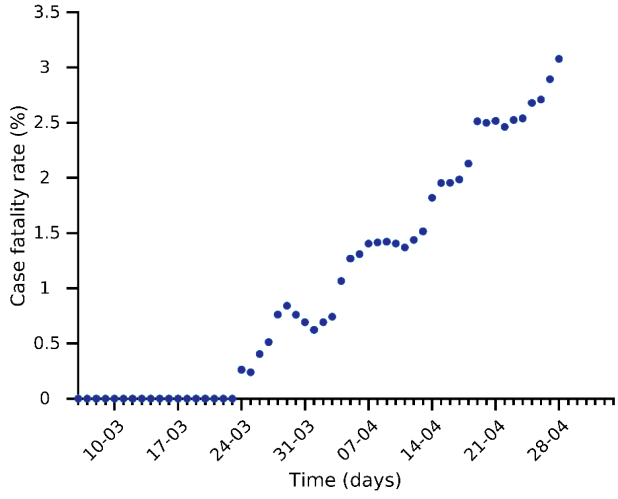




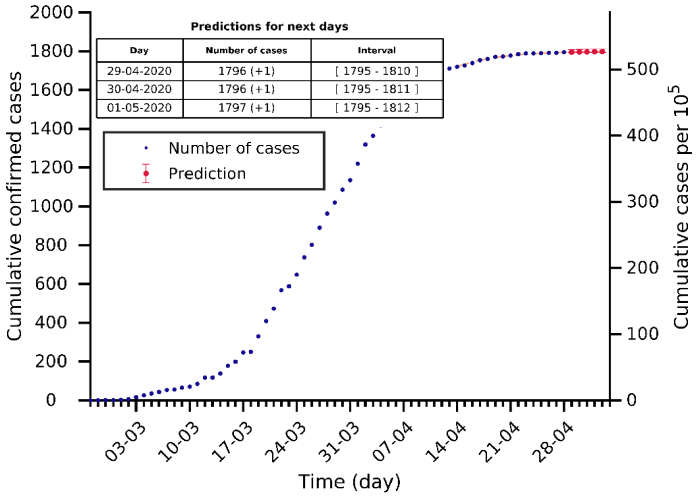


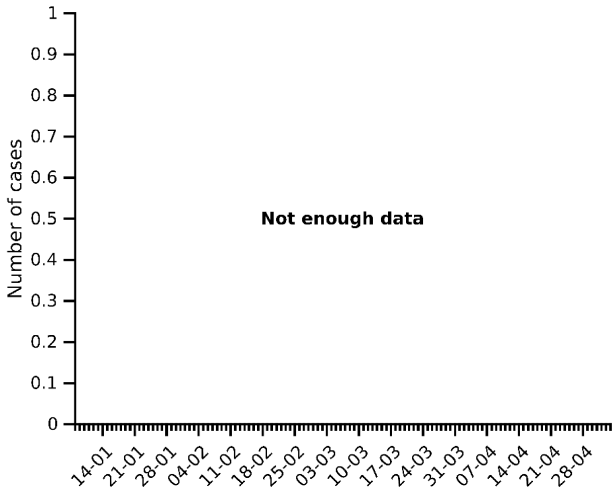


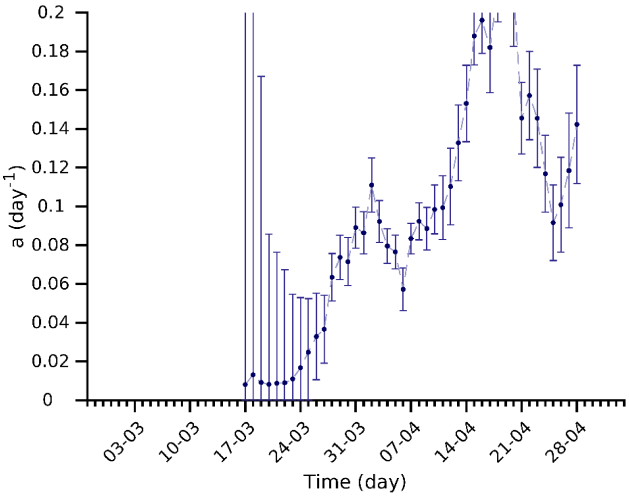


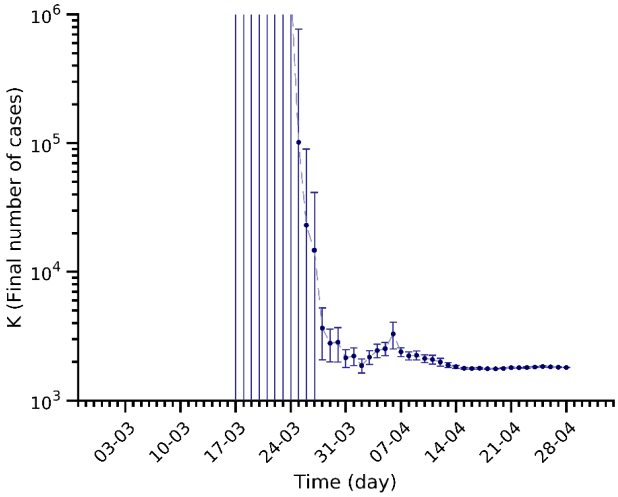


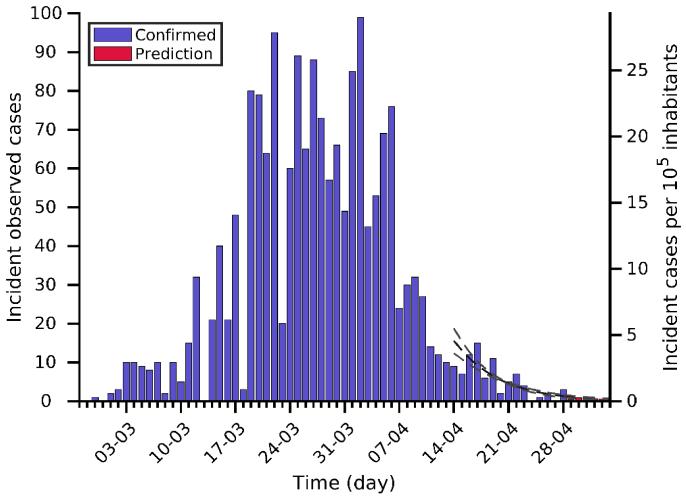
Iceland 28-04-2020. Population: 0.3M. Current cumulated incidence: 526/10^5

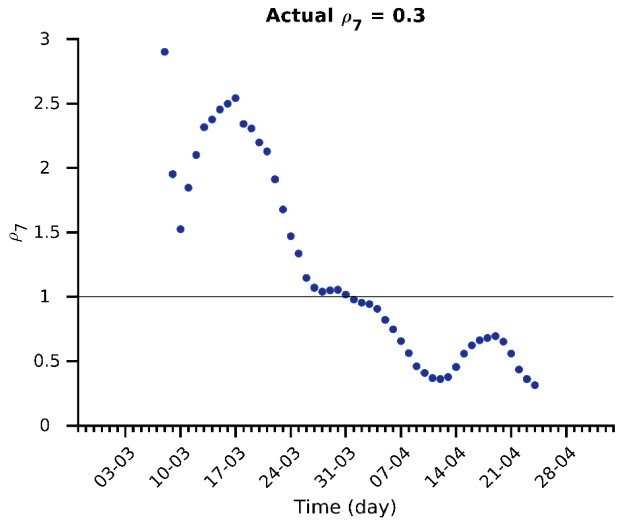


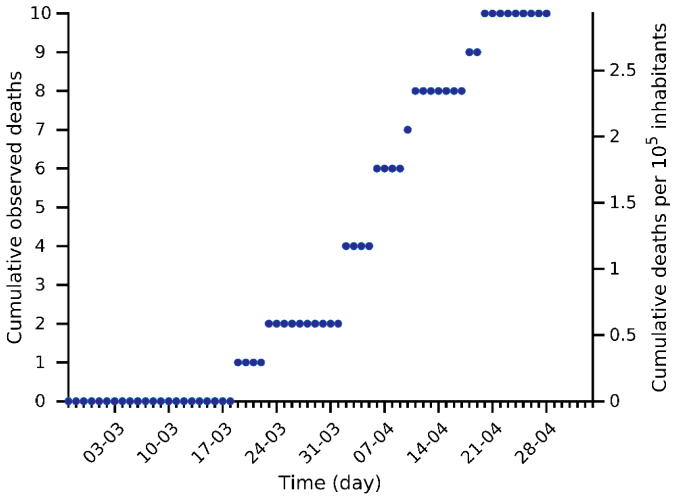


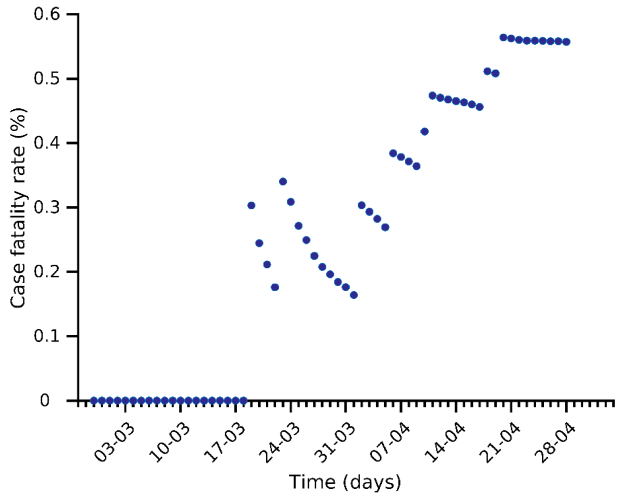




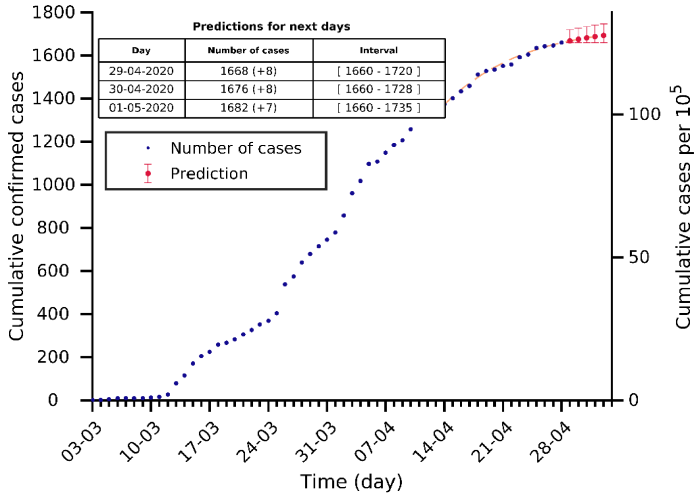


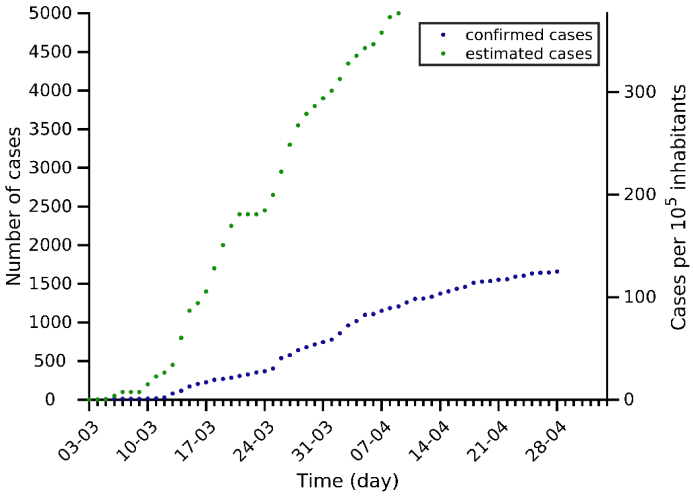


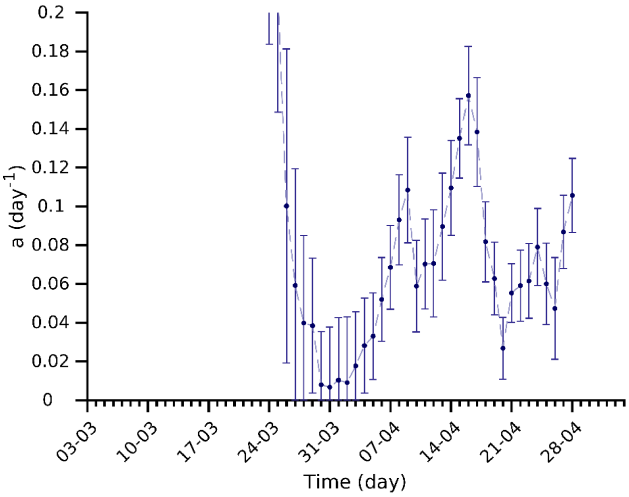


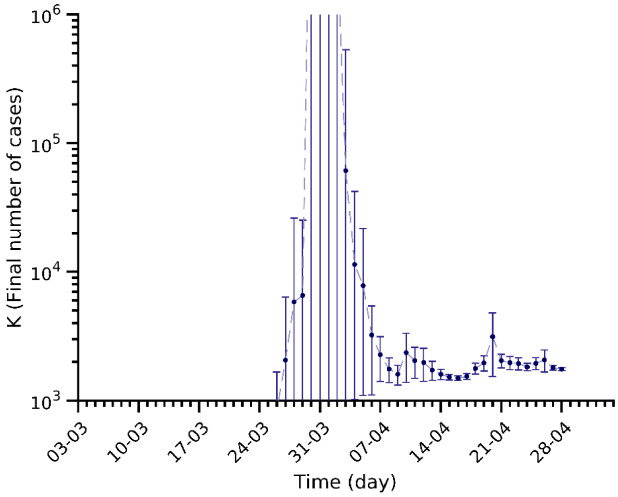


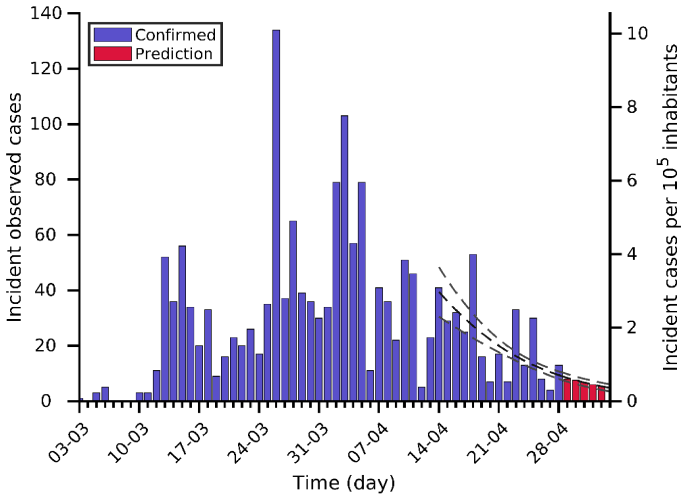
Estonia 28-04-2020. Population: 1.3M. Current cumulated incidence: $125/10^5$

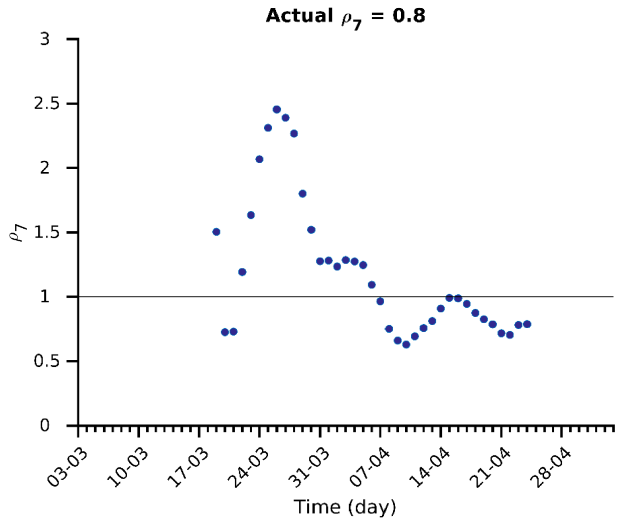


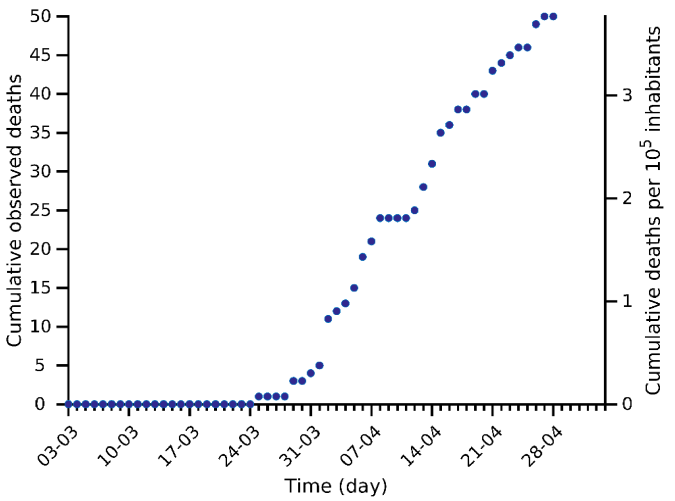


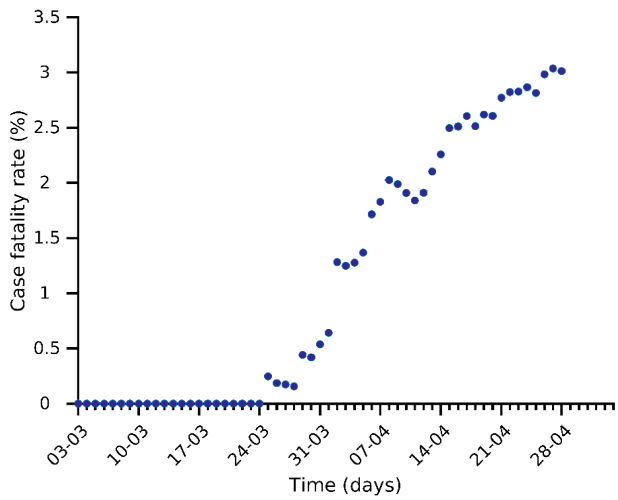




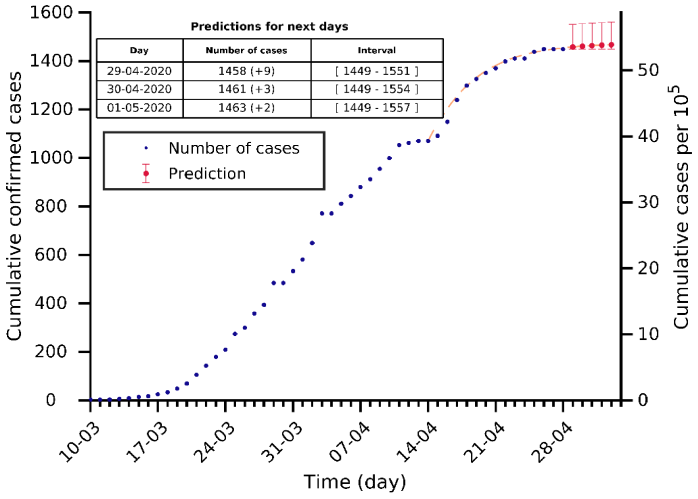


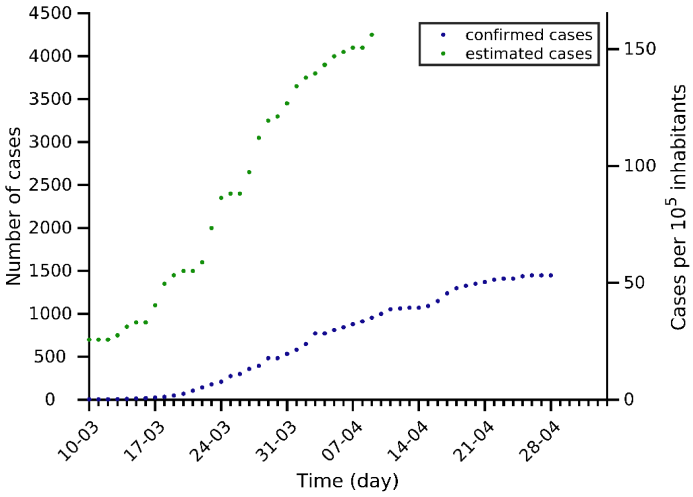


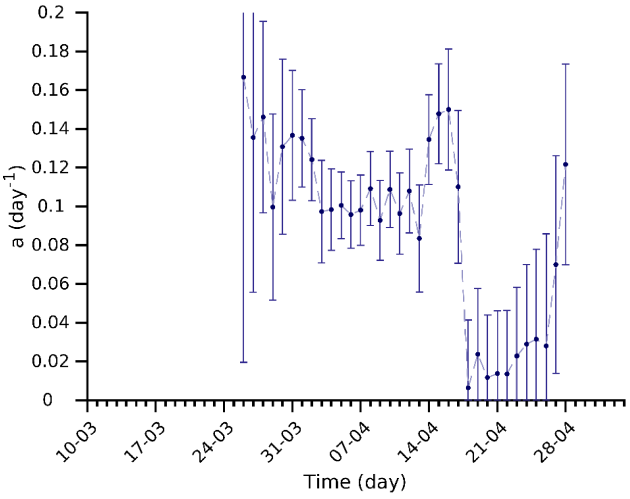


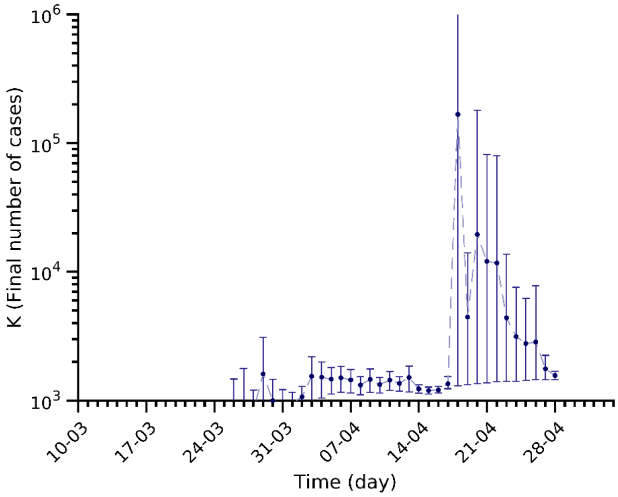


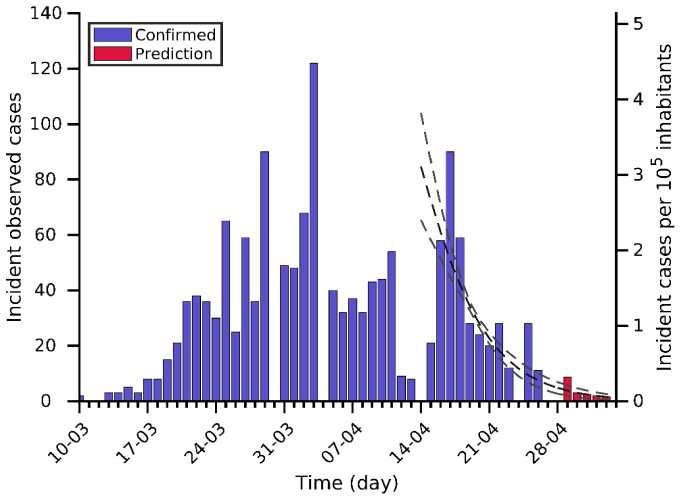
Lithuania 28-04-2020. Population: 2.7M. Current cumulated incidence: 53/10^5

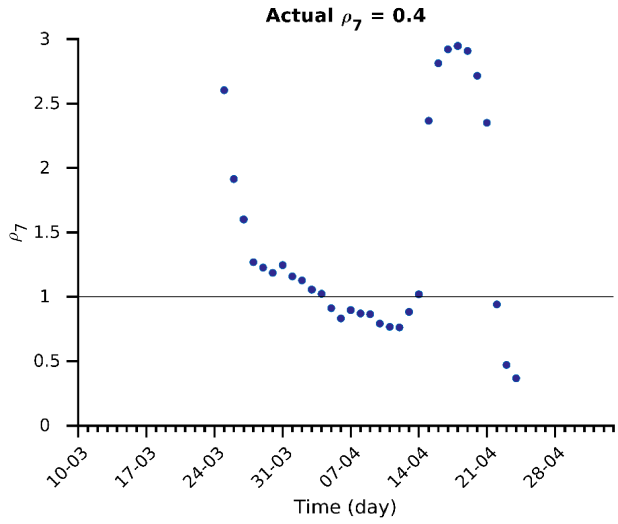


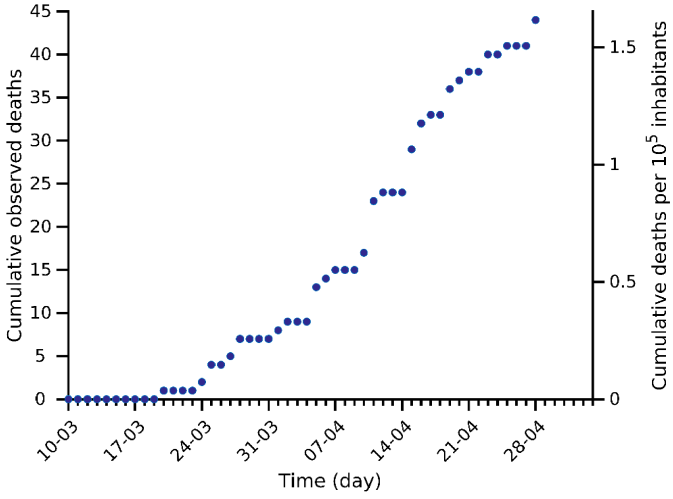


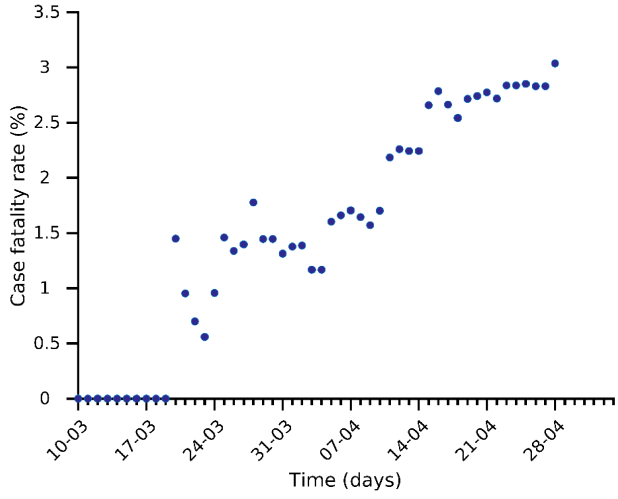




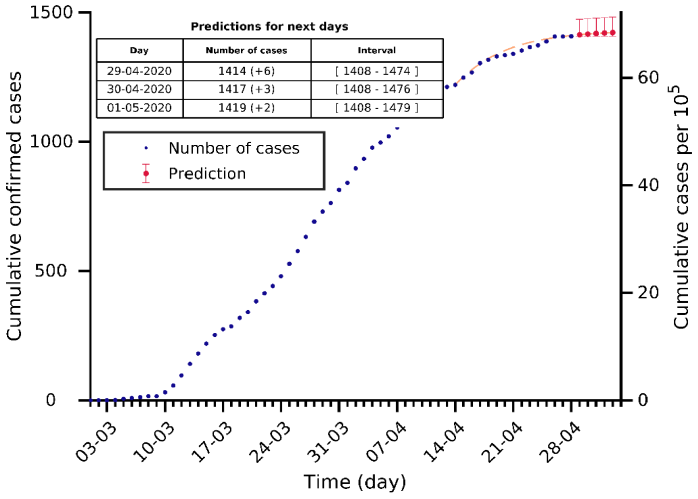


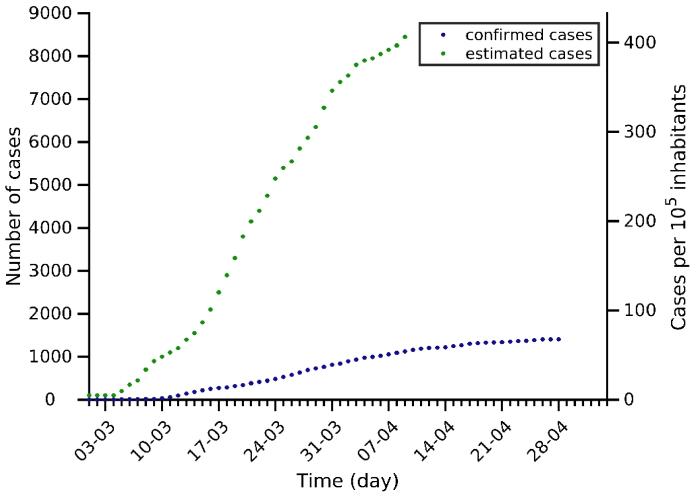


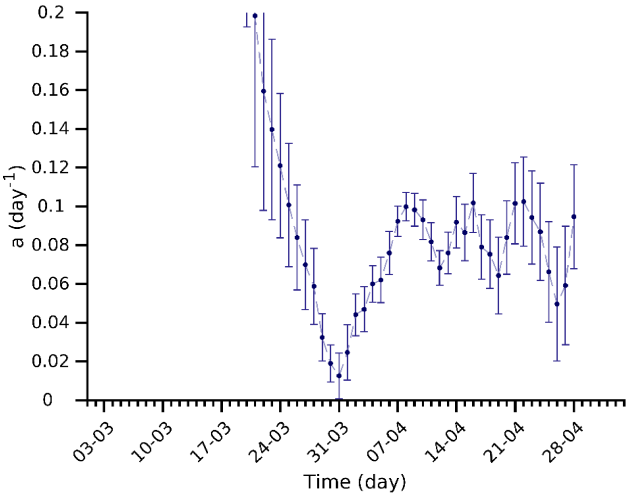


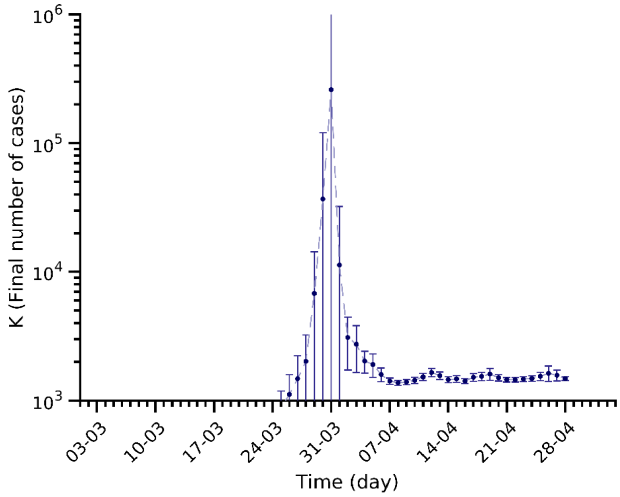


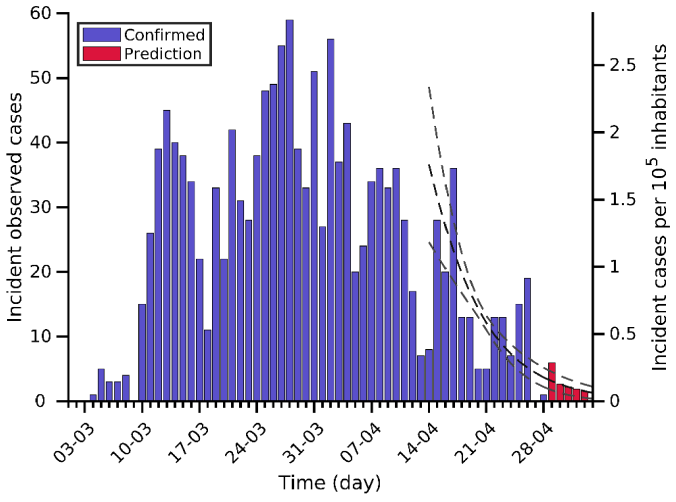
Slovenia 28-04-2020. Population: 2.1M. Current cumulated incidence: 68/10^5

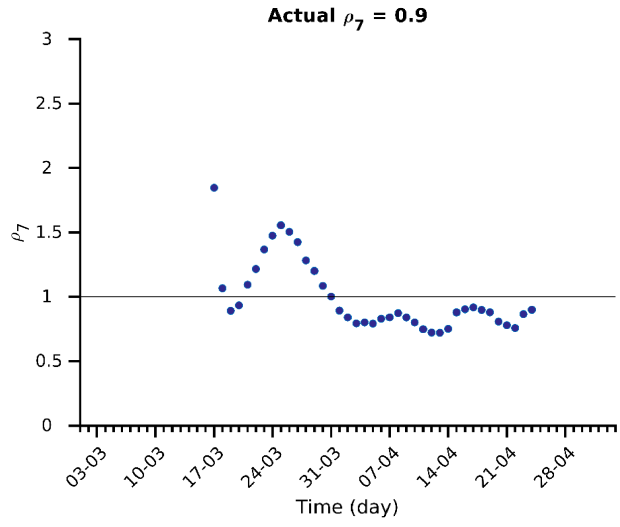


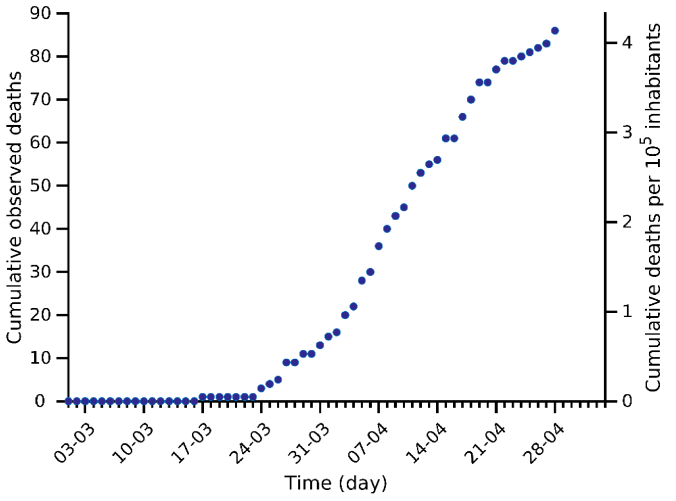


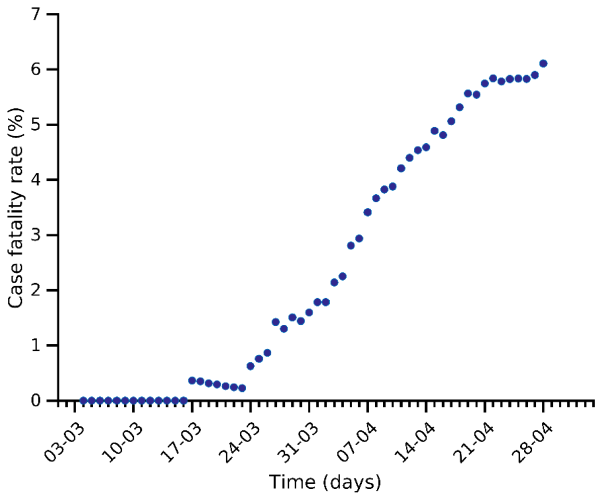




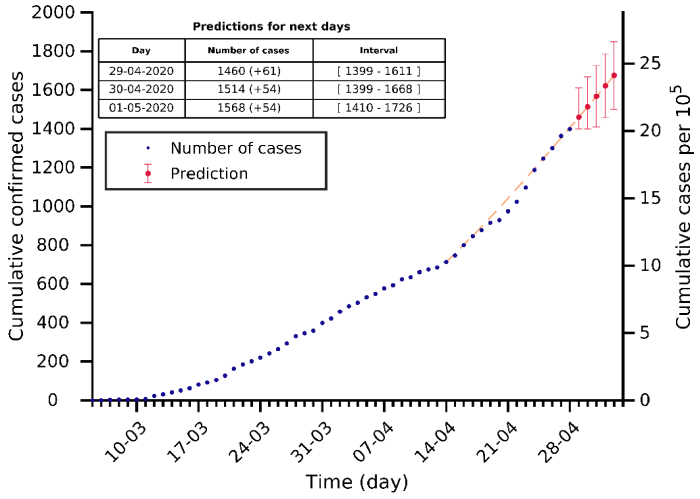


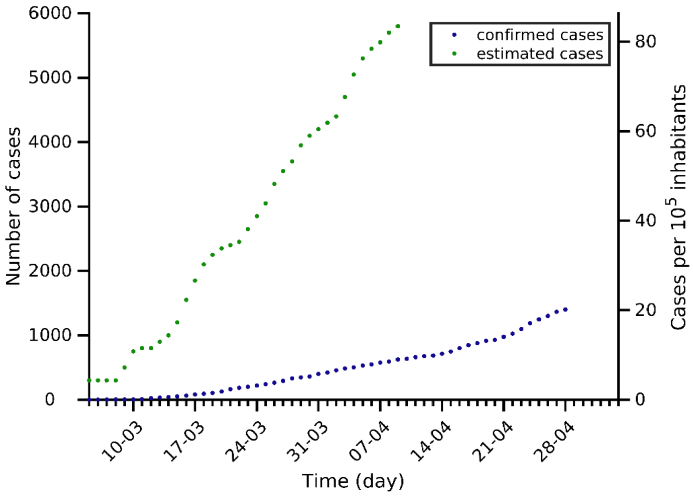


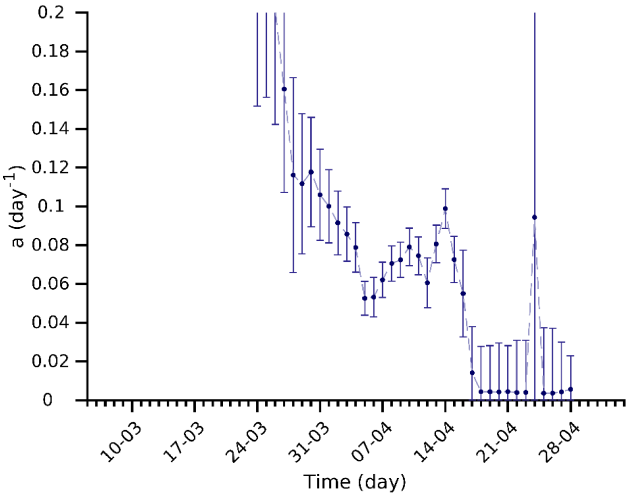


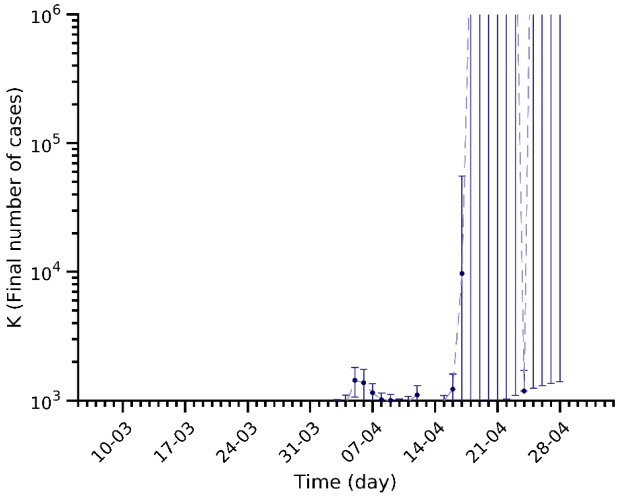


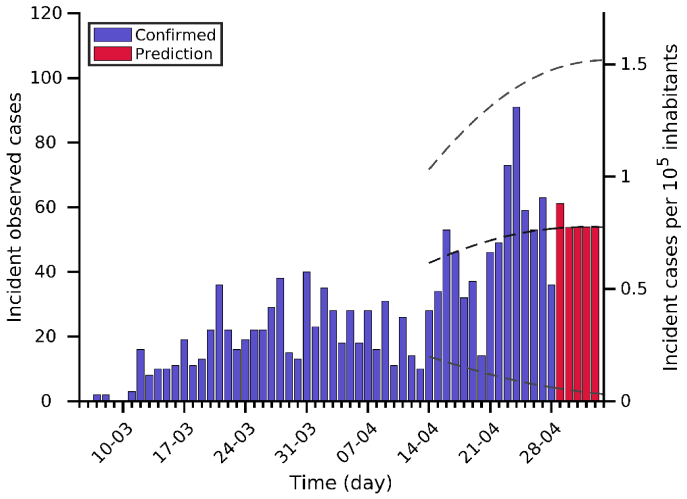
Bulgaria 28-04-2020. Population: 6.9M. Current cumulated incidence: 20/10^5

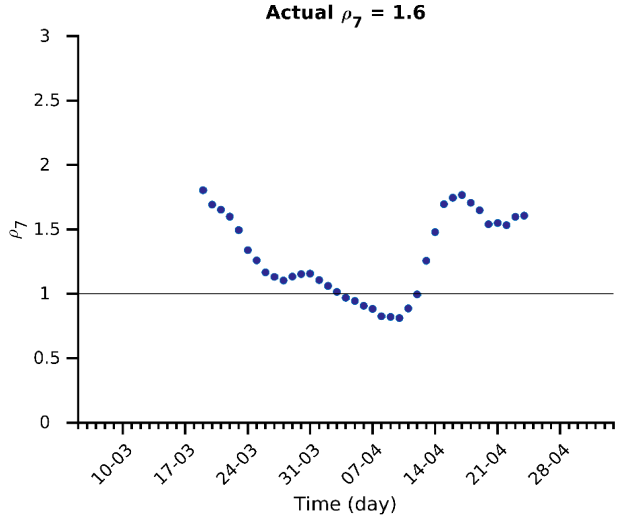


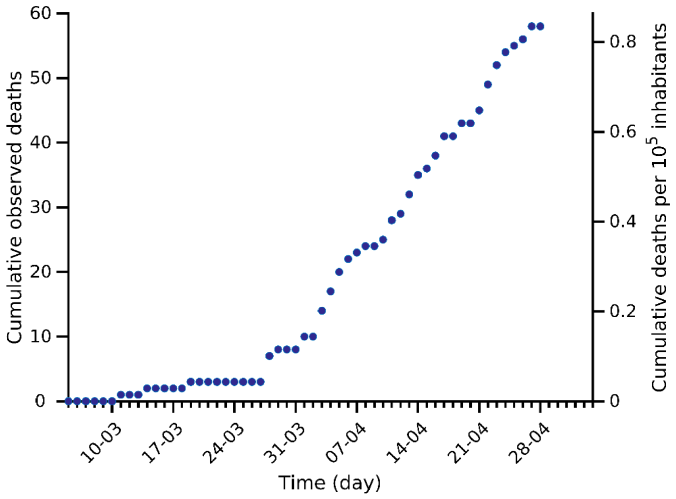


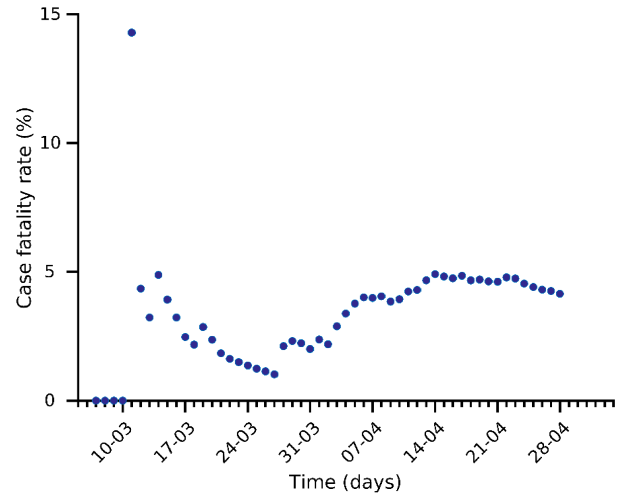




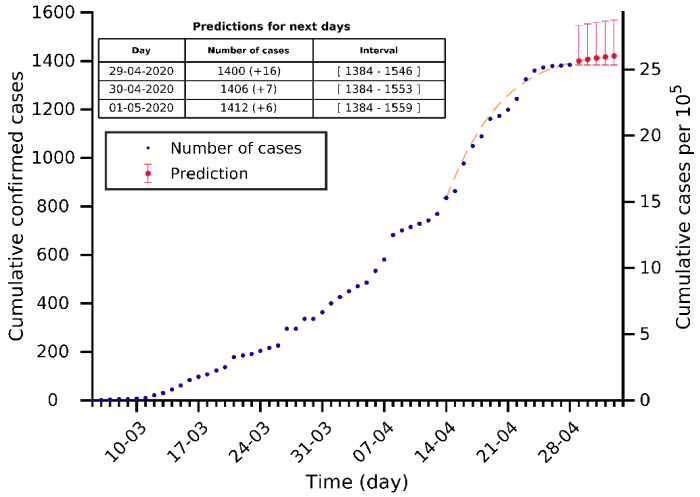


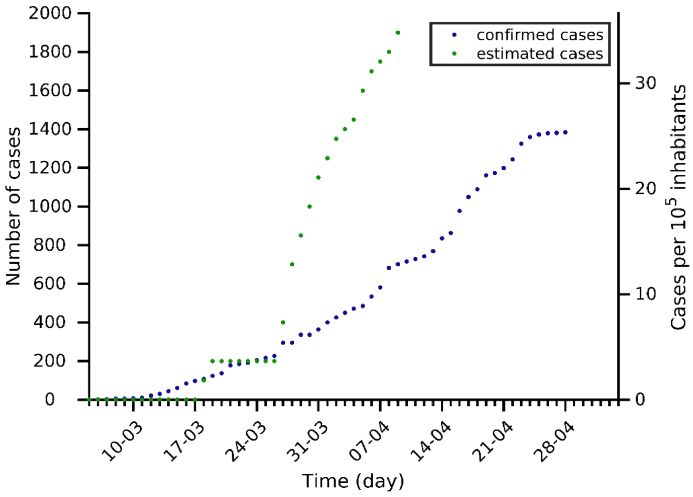


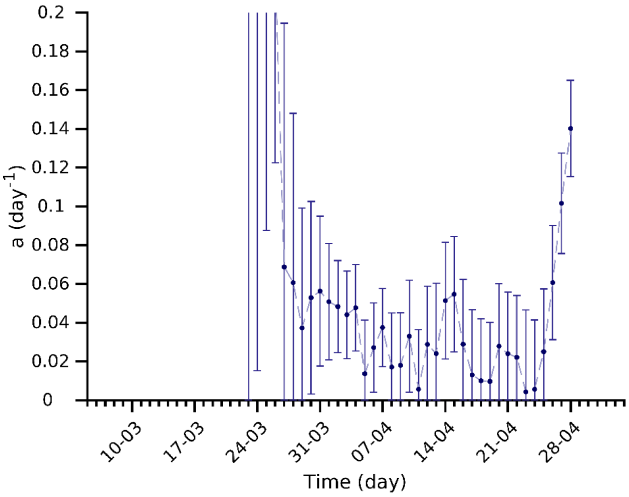


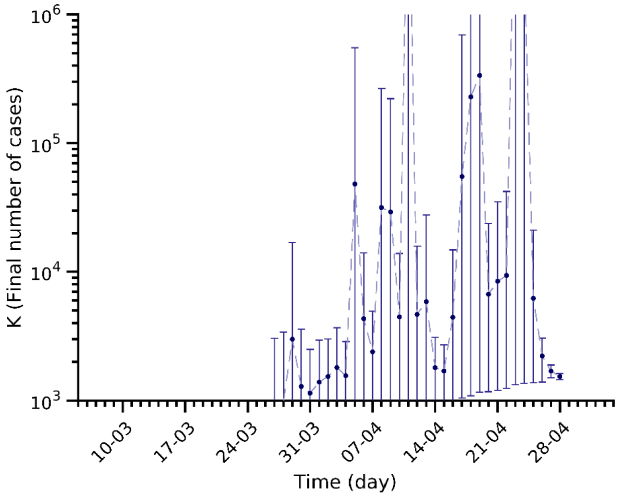


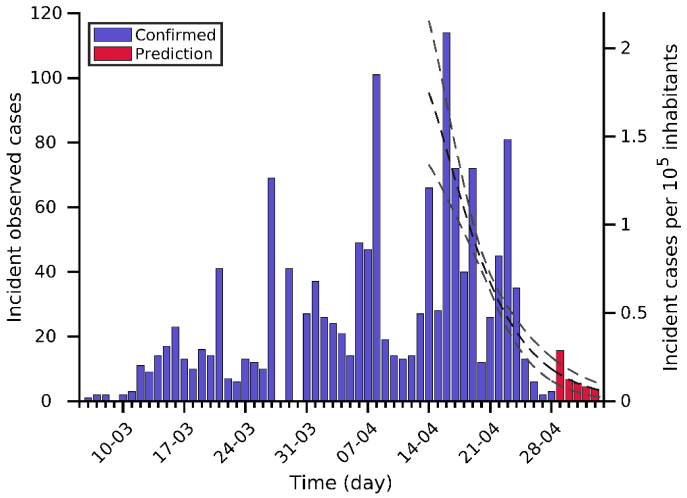
Slovakia 28-04-2020. Population: 5.5M. Current cumulated incidence: 25/10^5

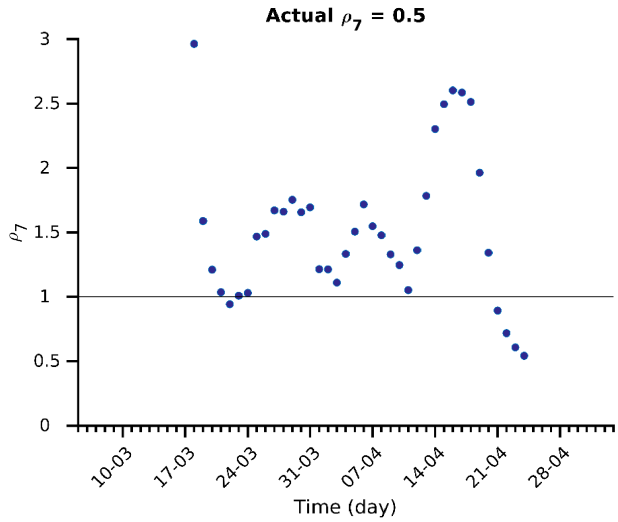


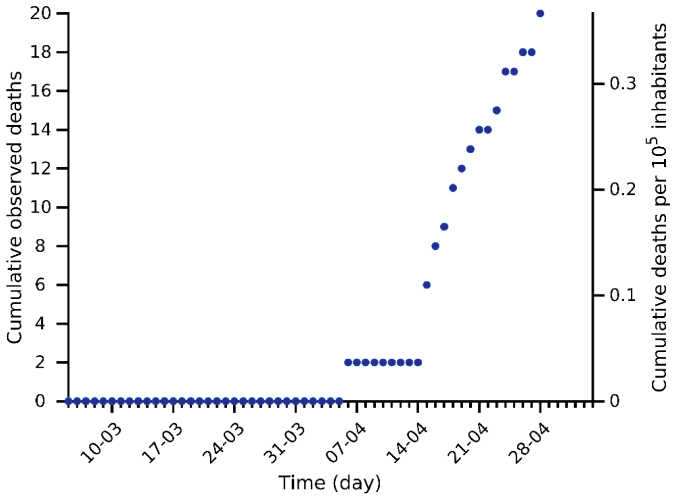


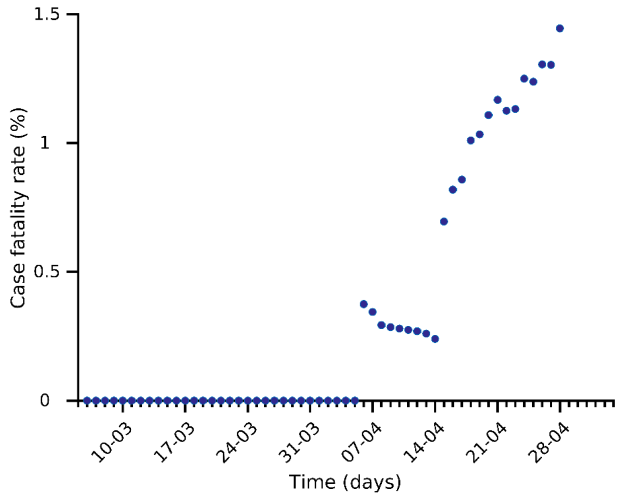




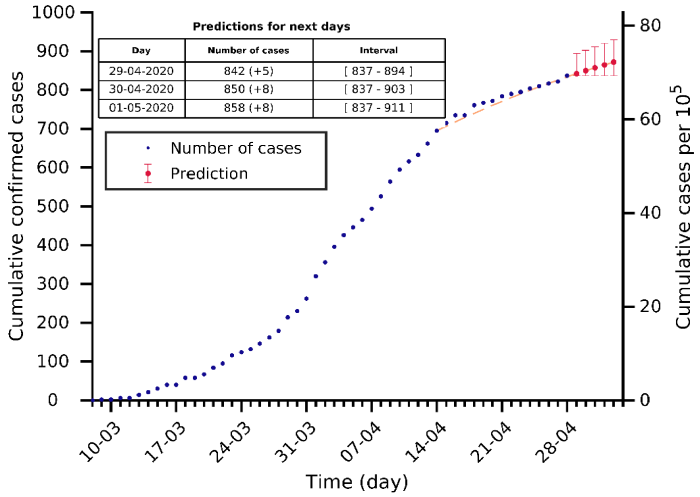


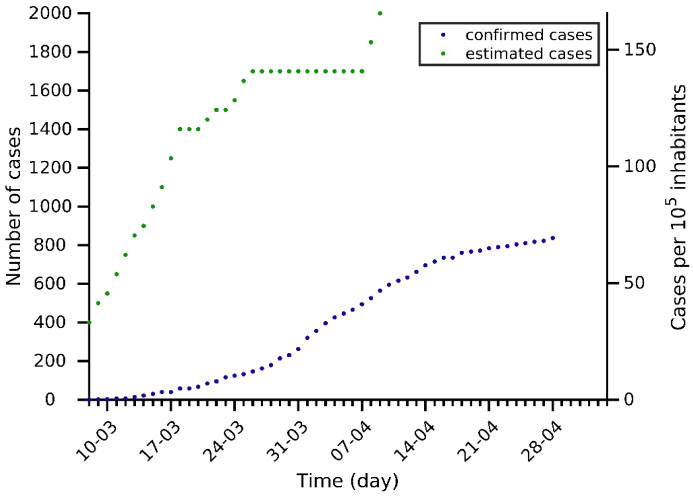


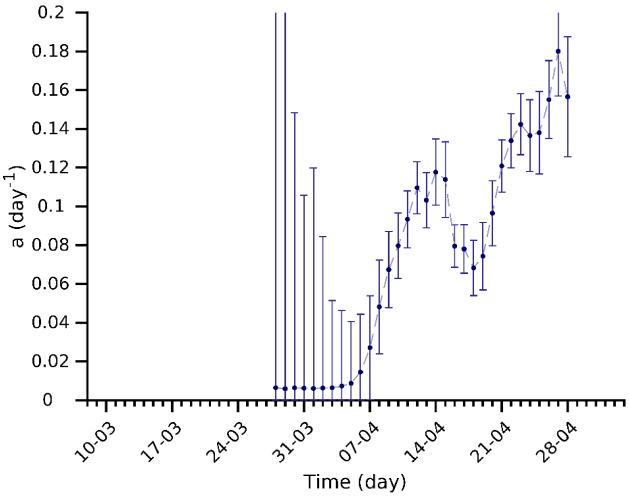


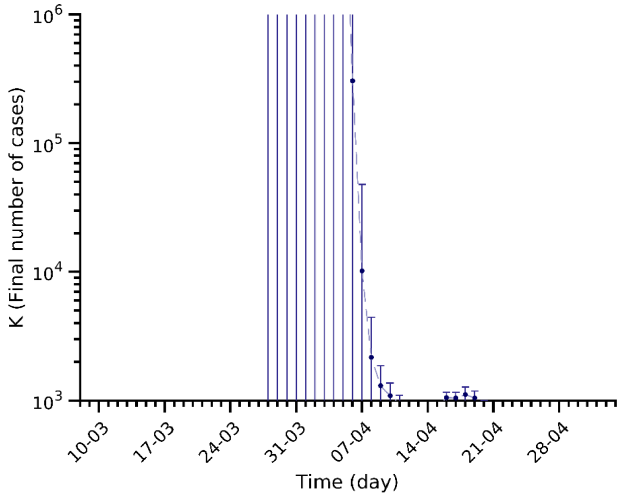


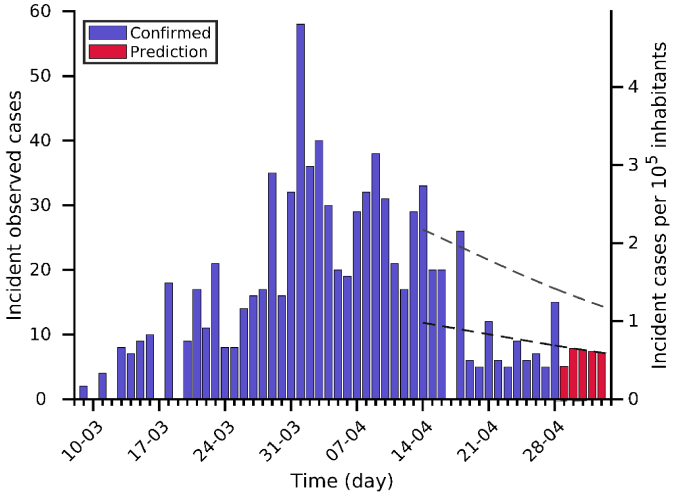
Cyprus 28-04-2020. Population: 1.2M. Current cumulated incidence: 69/10^5

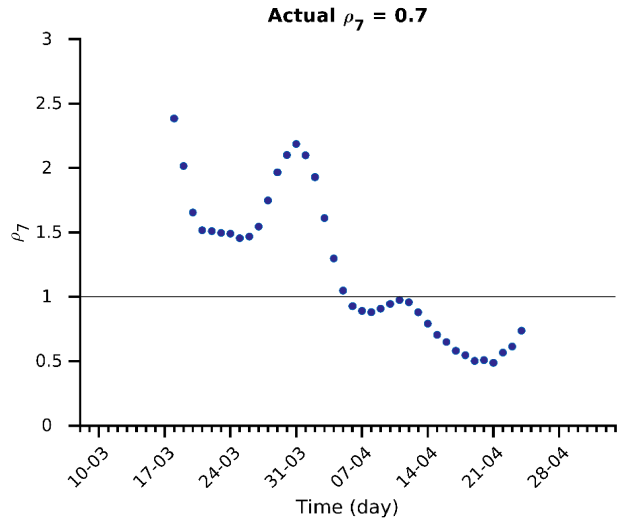


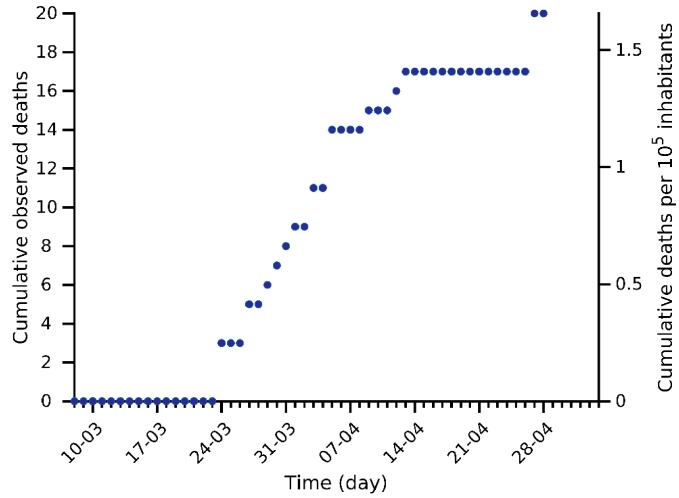


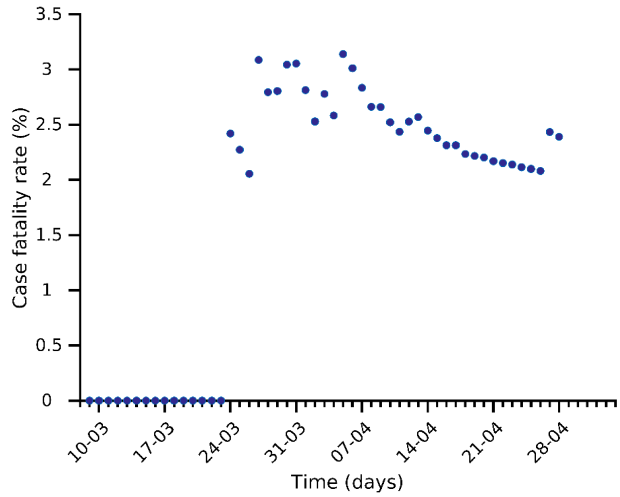




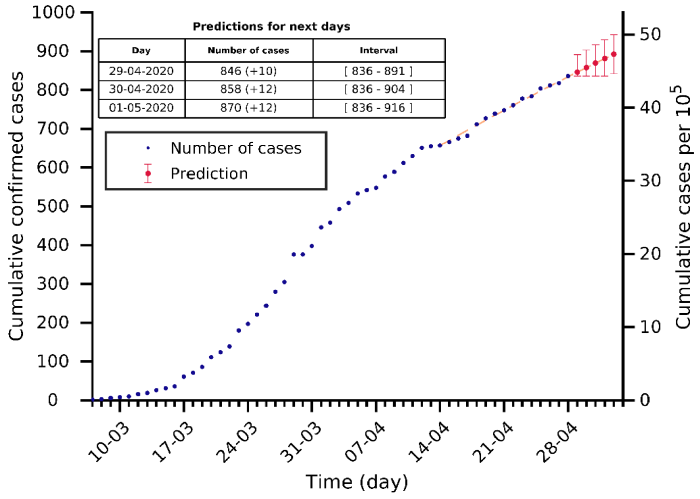


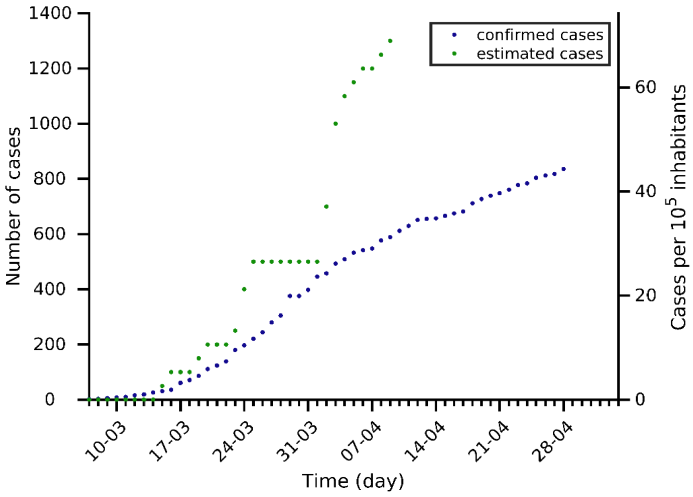


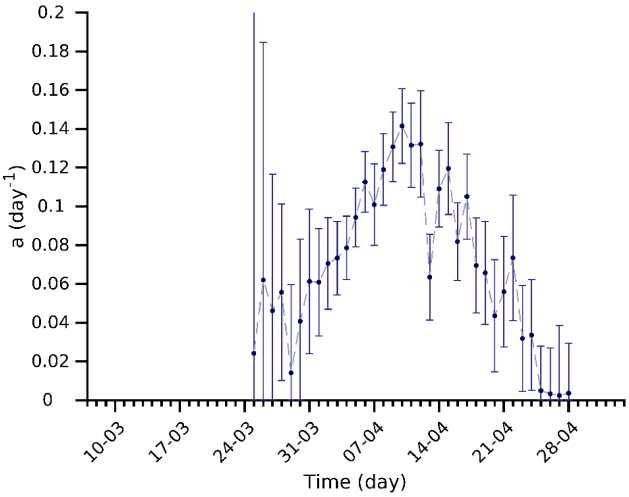


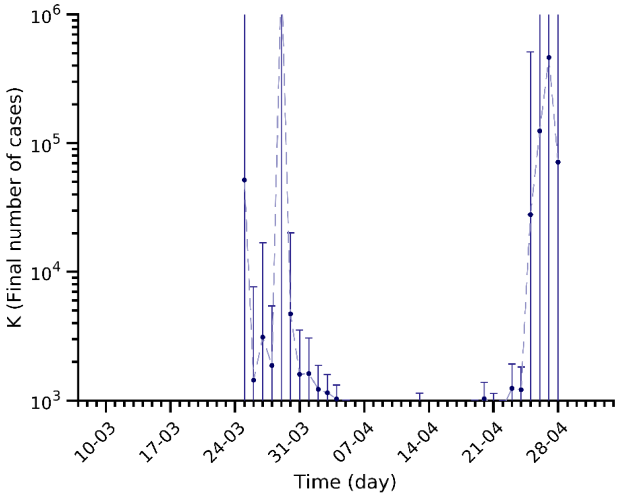


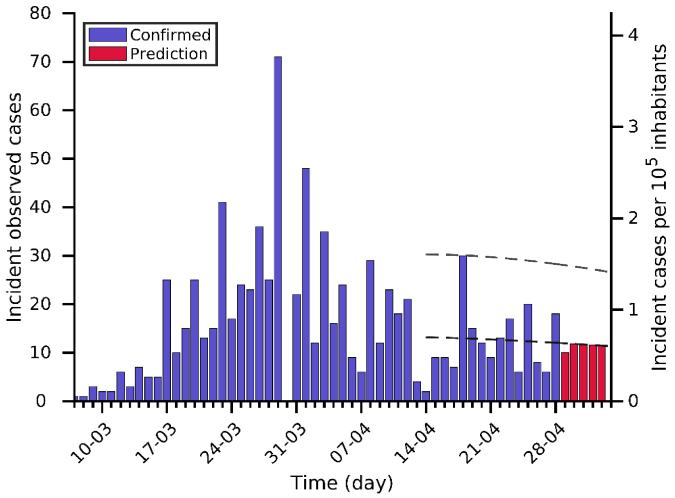
Latvia 28-04-2020. Population: 1.9M. Current cumulated incidence: 44/10⁵

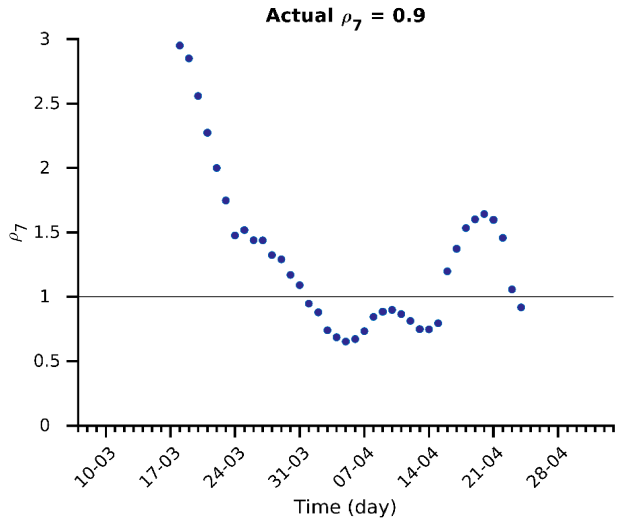


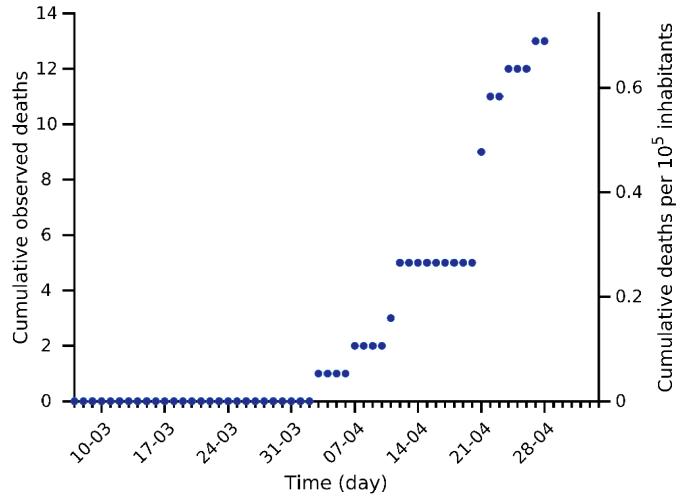


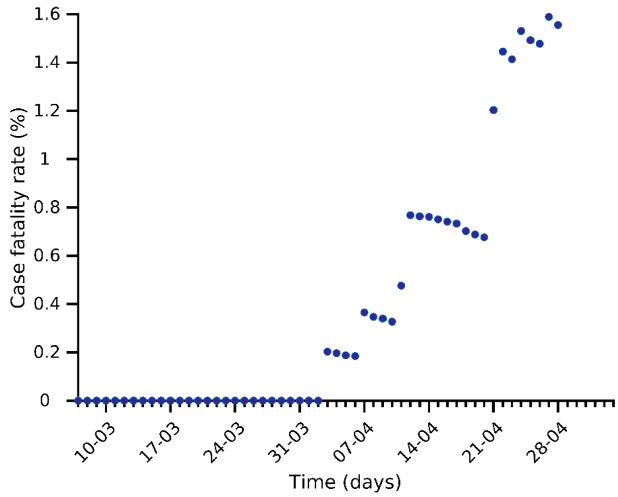




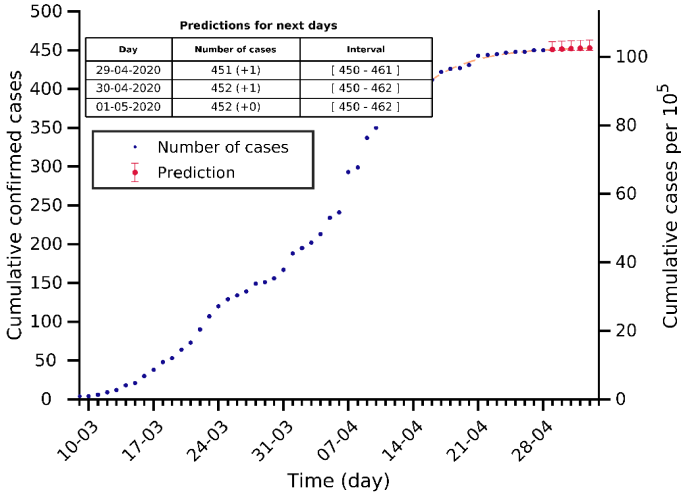


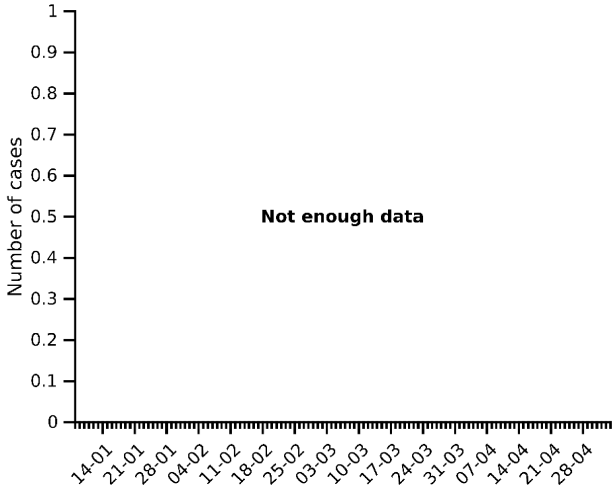


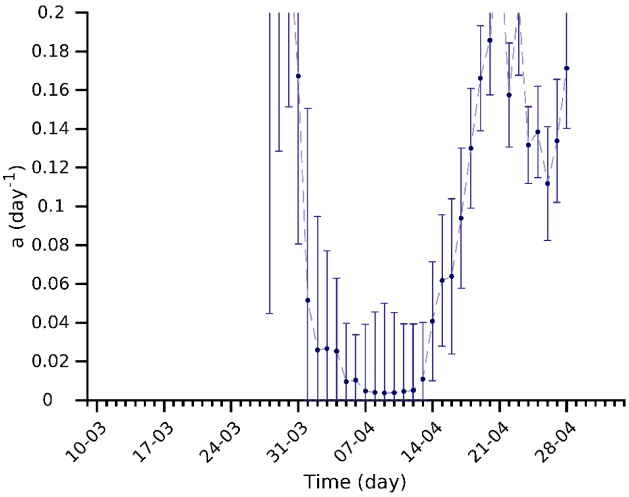


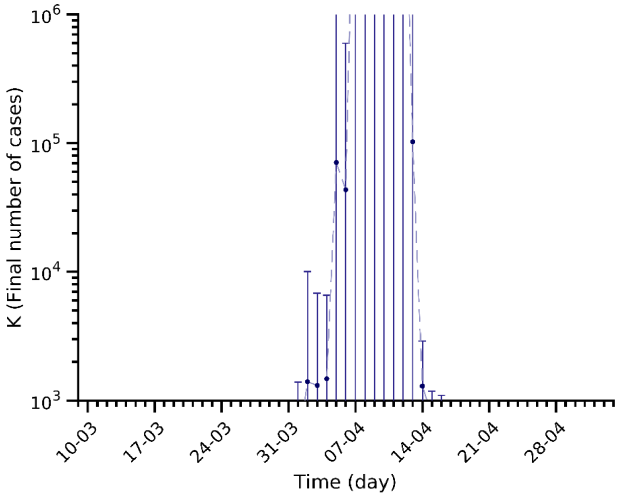


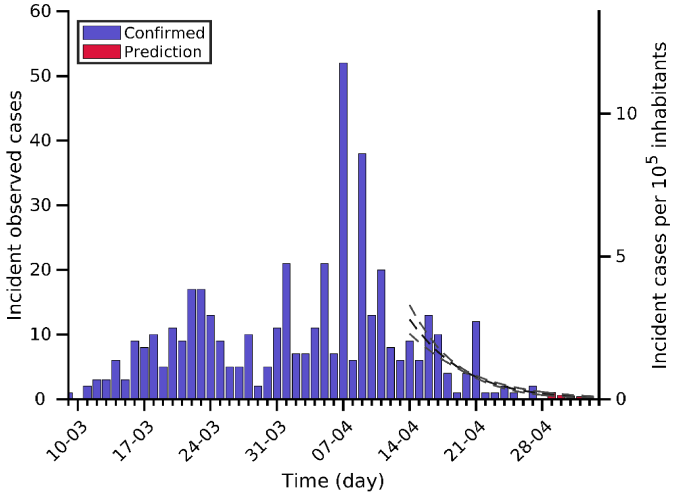
Malta 28-04-2020. Population: 0.4M. Current cumulated incidence: $102/10^5$

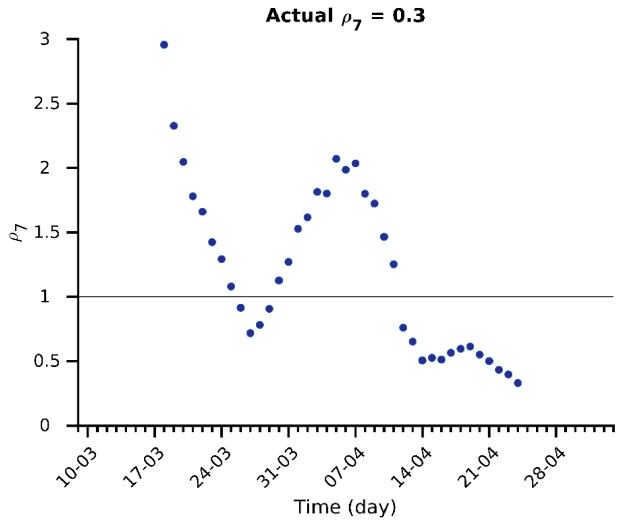


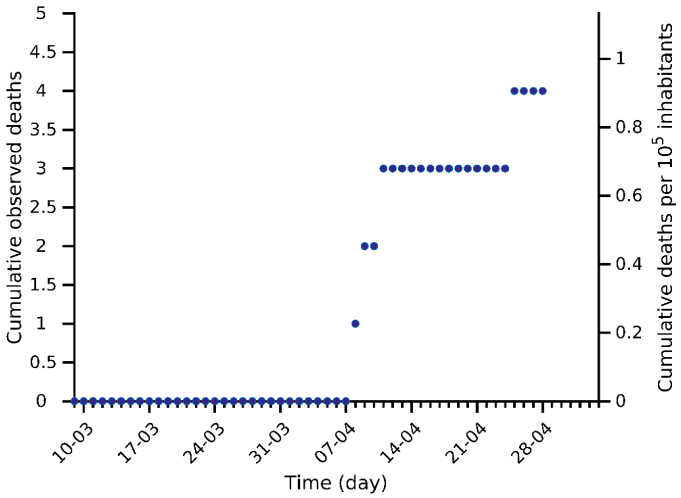


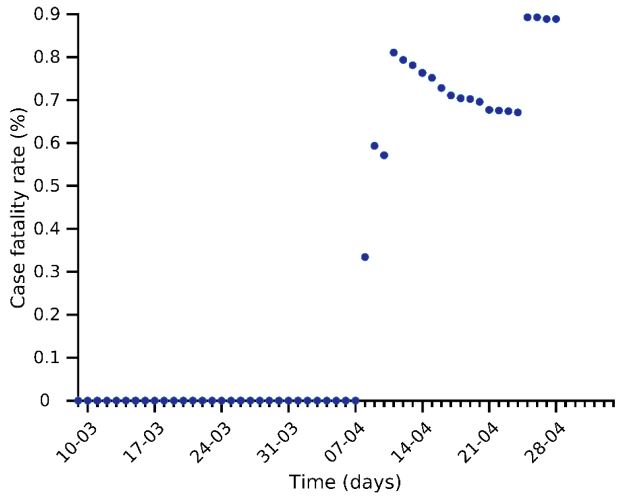








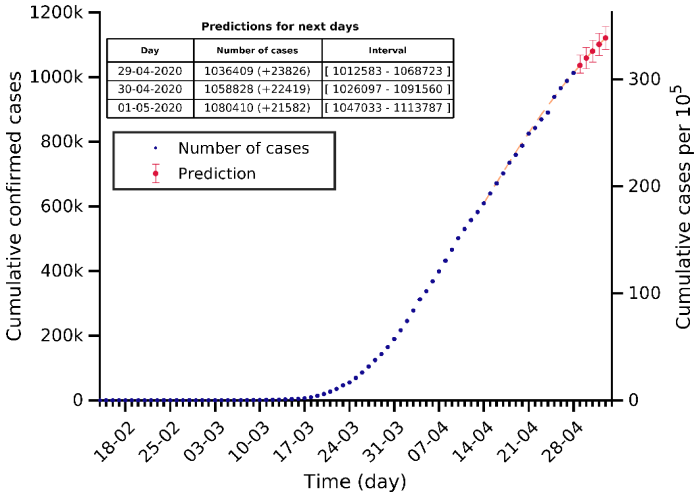


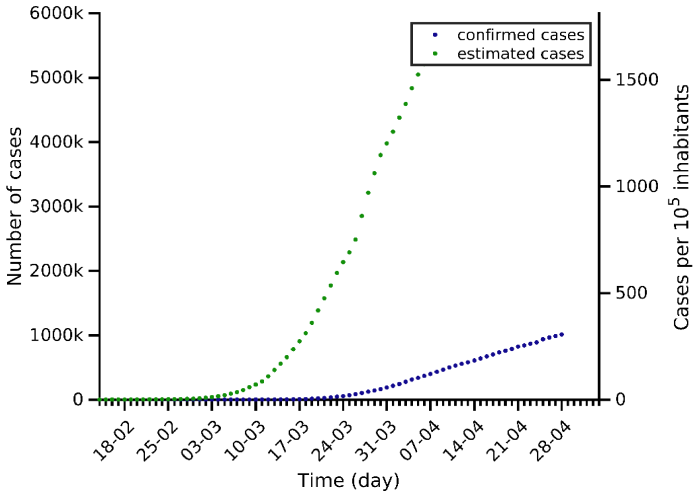


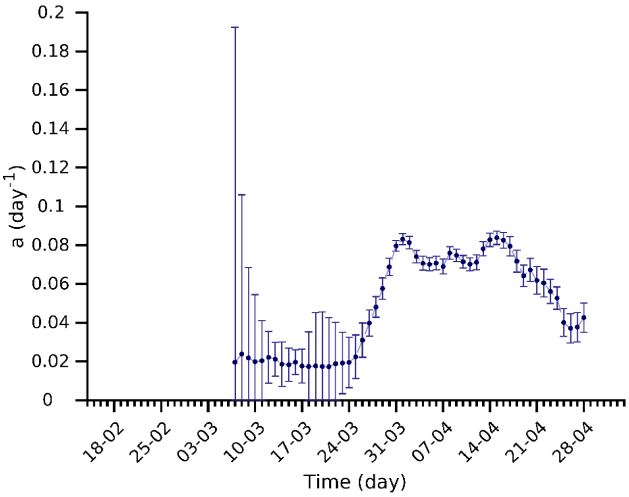
(2) Analysis and prediction of COVID-19 for other countries

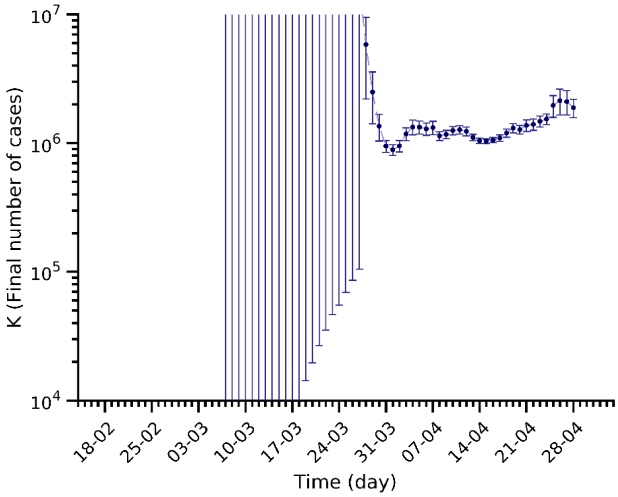
Data obtained from https://www.ecdc.europa.eu/en/geographical-distribution-2019-ncov-cases

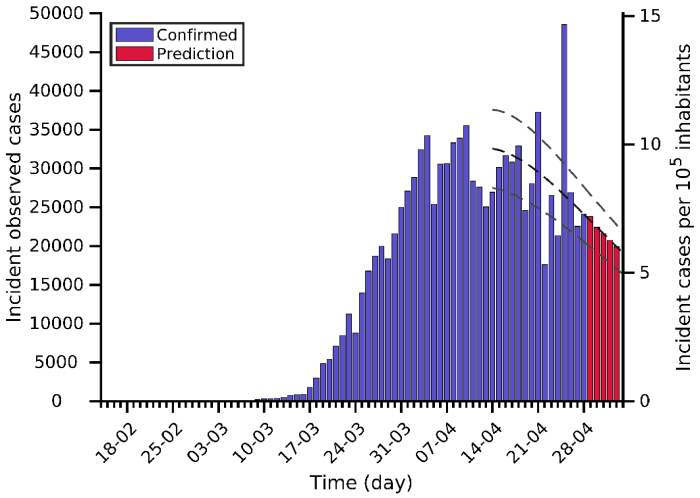
USA 28-04-2020. Population: 331.0M. Current cumulated incidence: 306/10^5

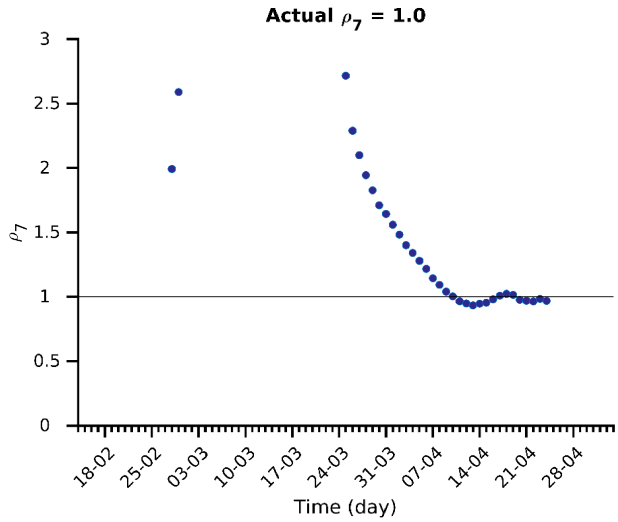


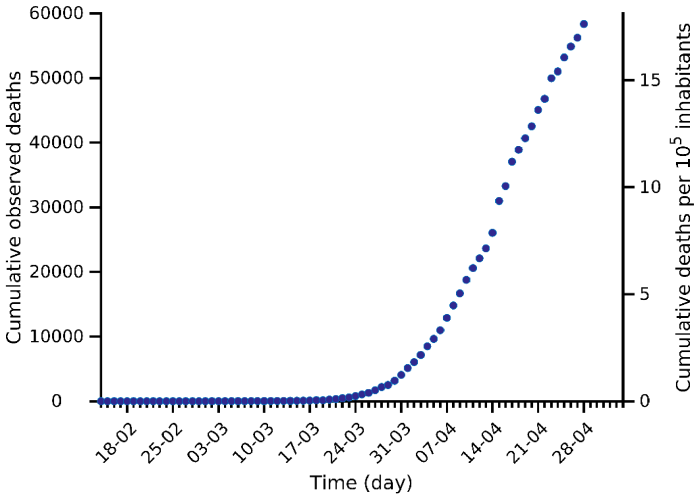


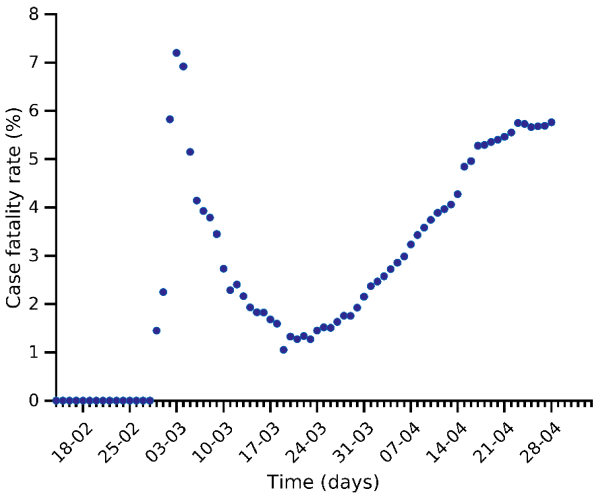




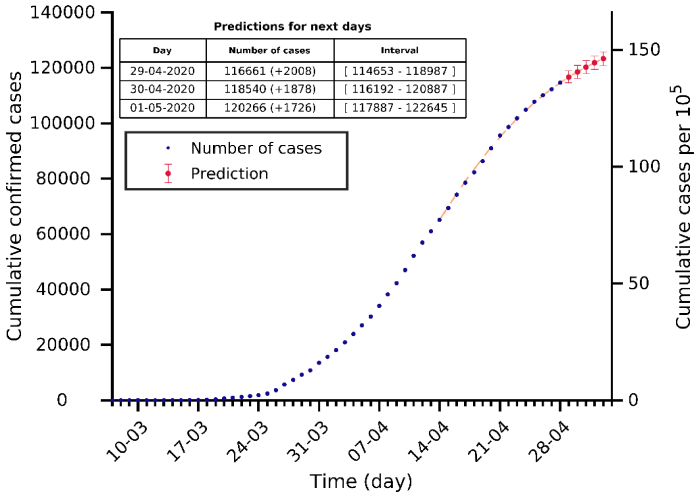


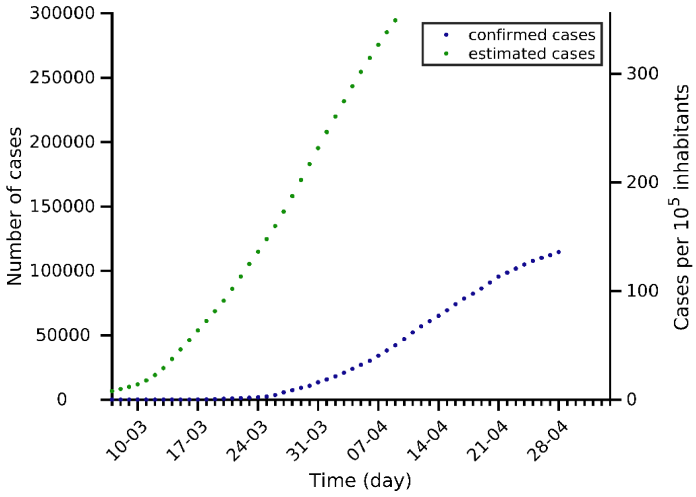


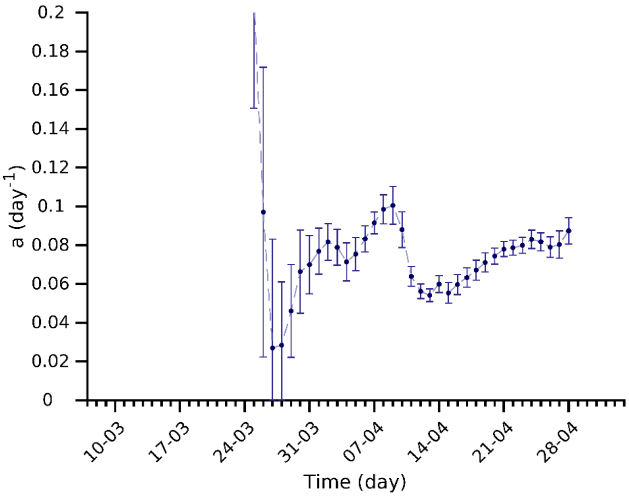


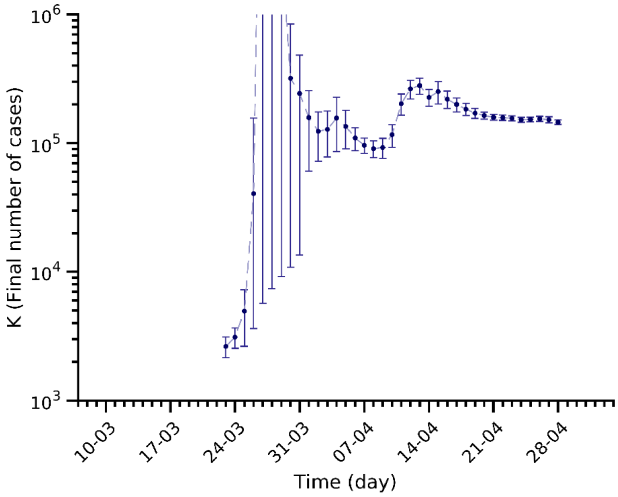


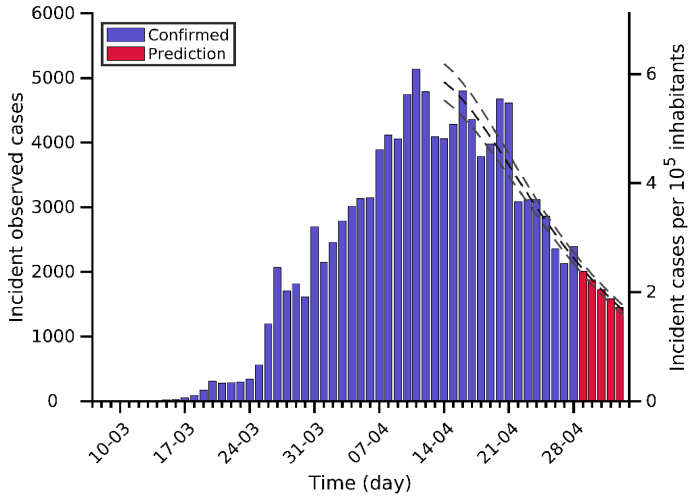
Turkey 28-04-2020. Population: 84.3M. Current cumulated incidence: 136/10⁵

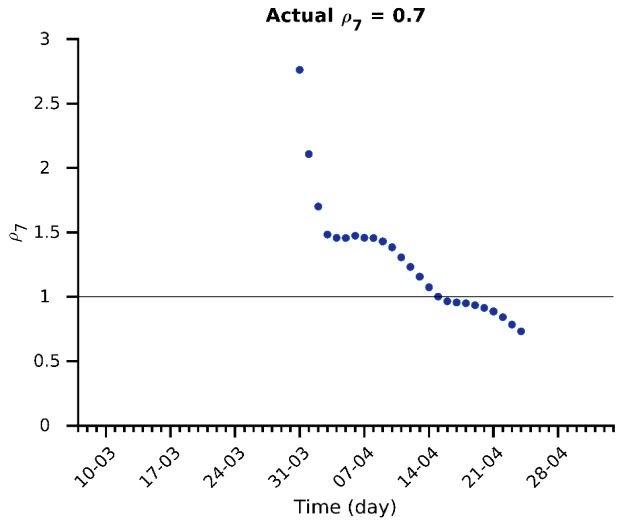


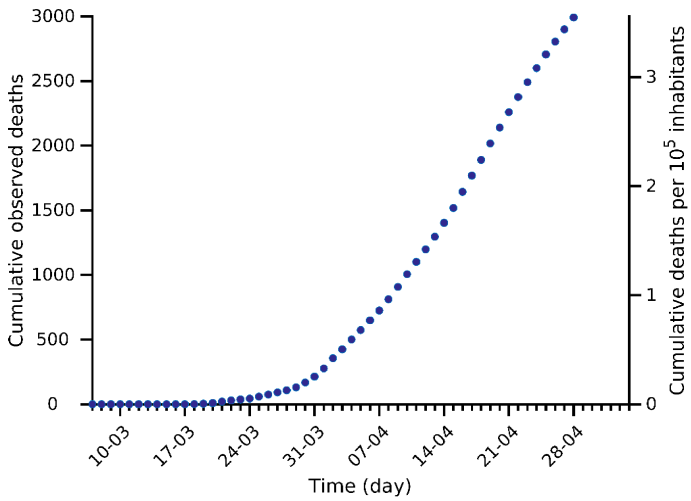


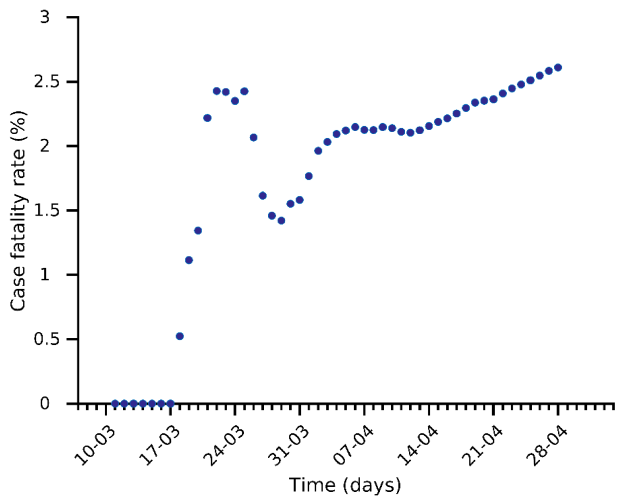




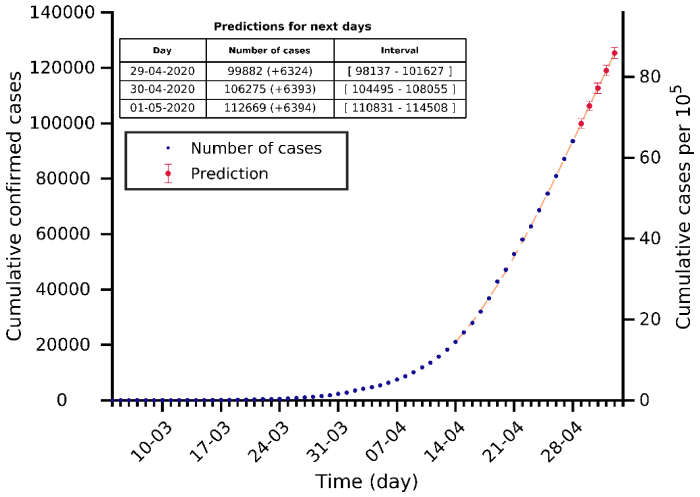


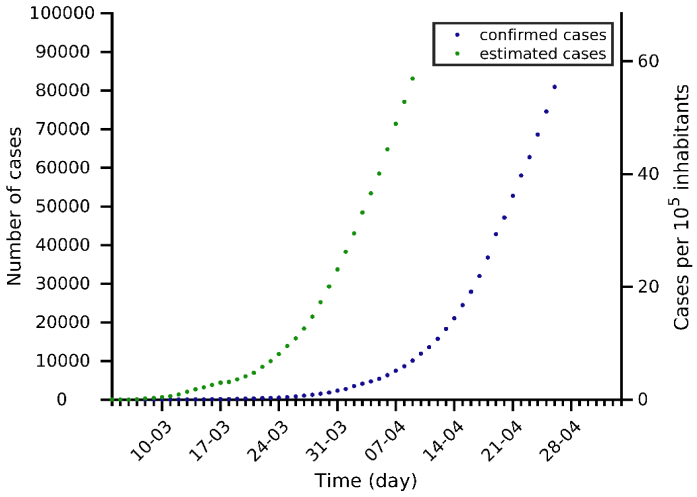


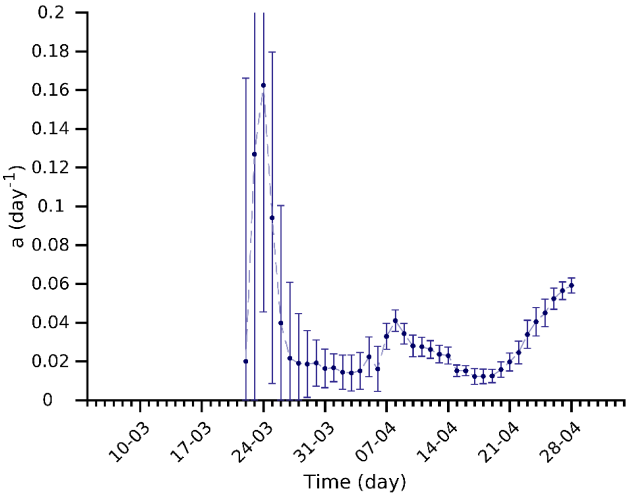


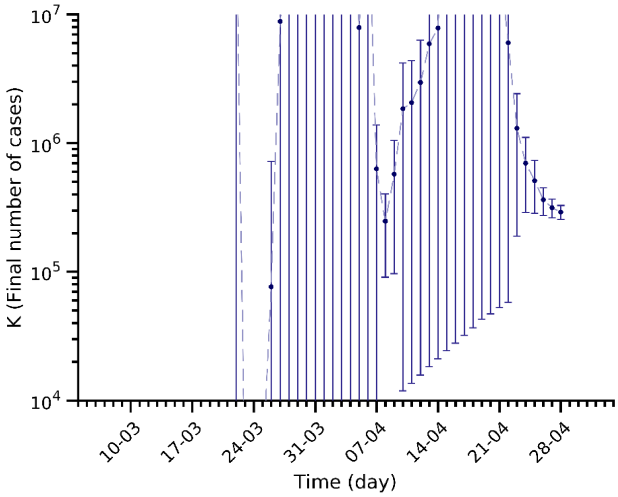


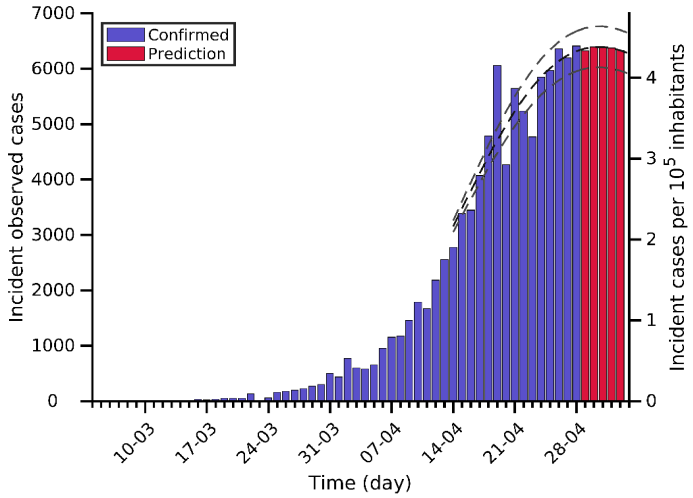
Russia 28-04-2020. Population: 145.9M. Current cumulated incidence: 64/10^5

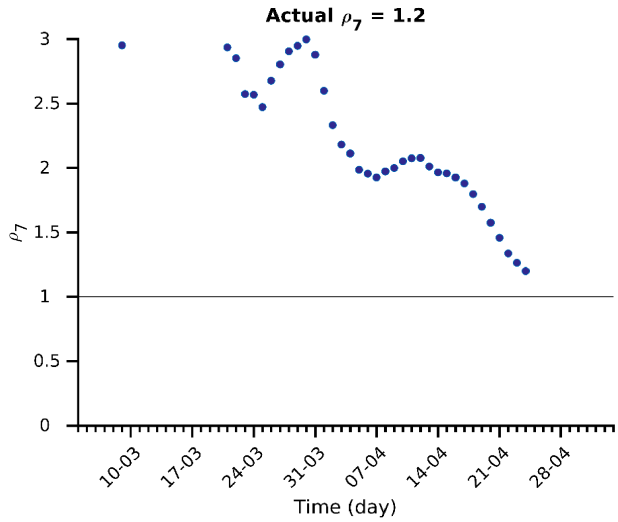


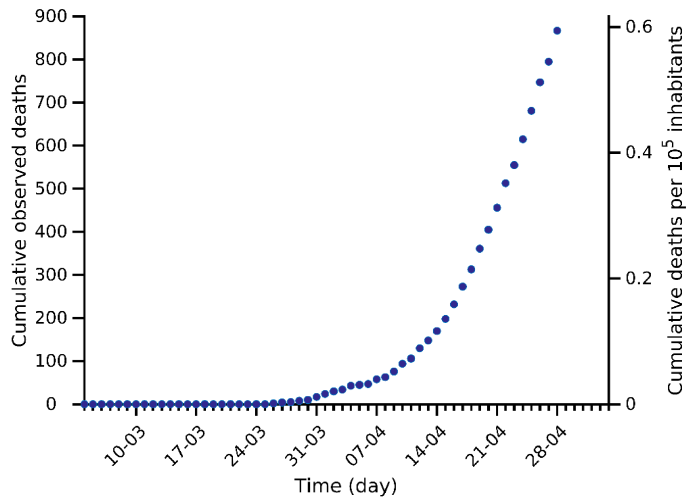


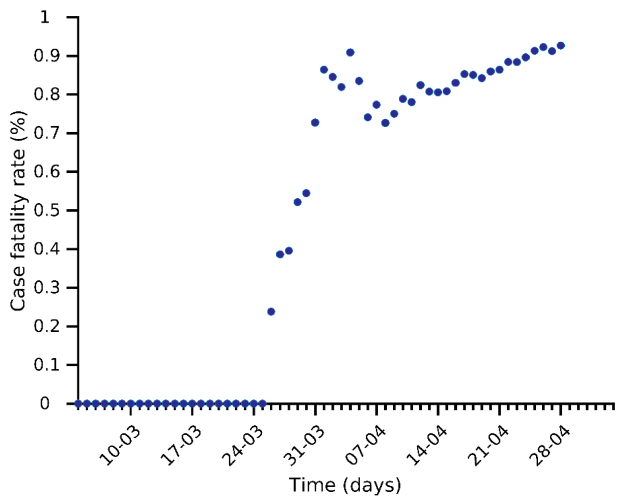




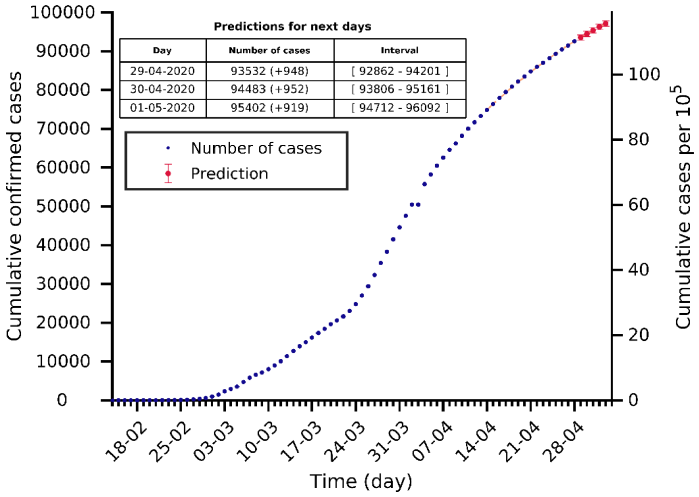


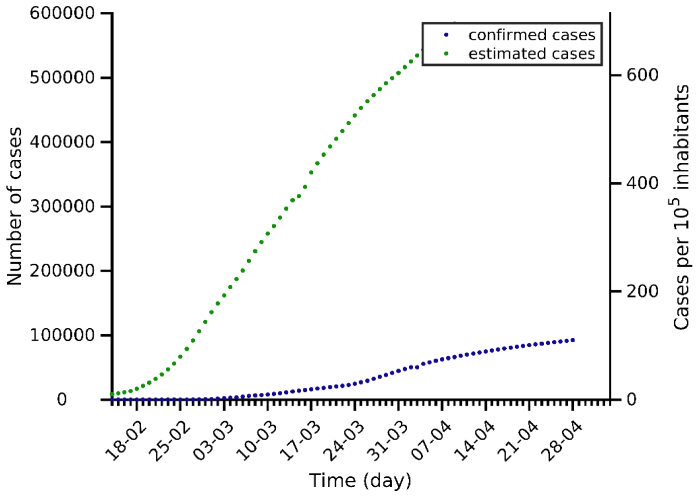


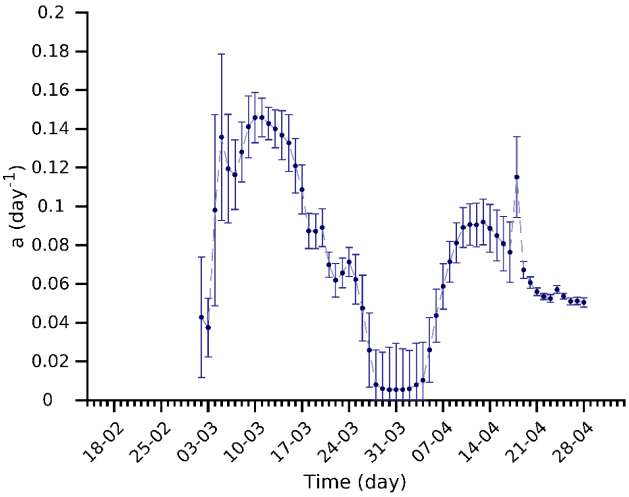


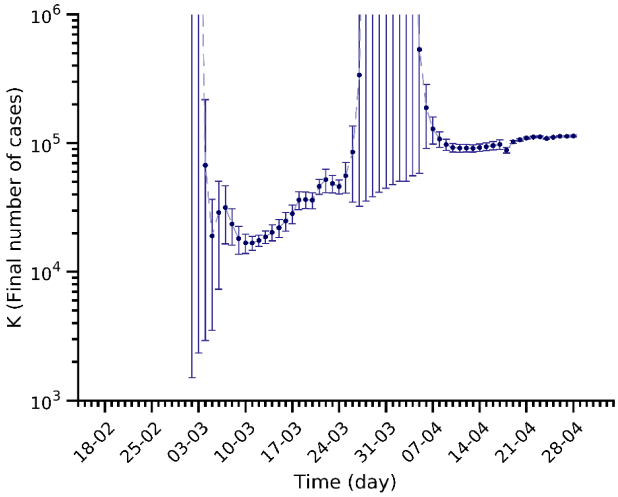


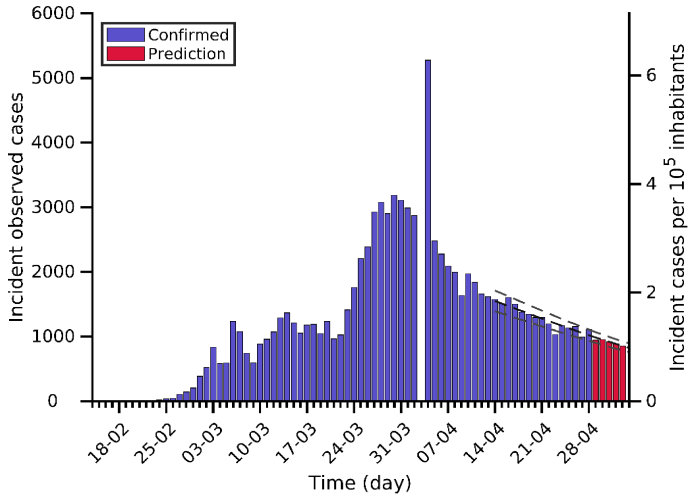
Iran 28-04-2020. Population: 84.0M. Current cumulated incidence: 110/10⁵

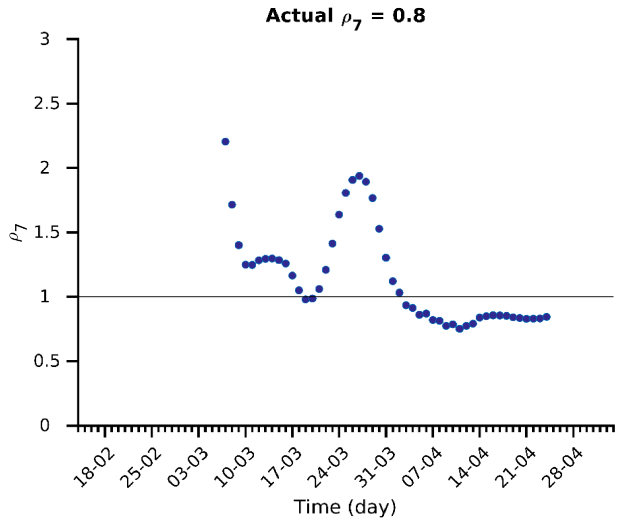


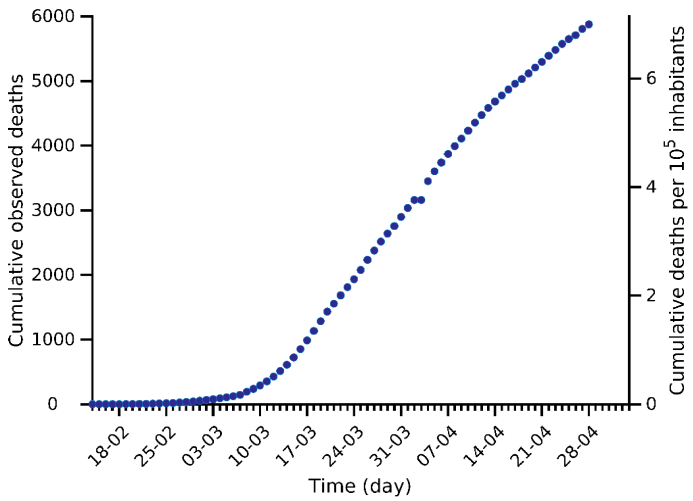


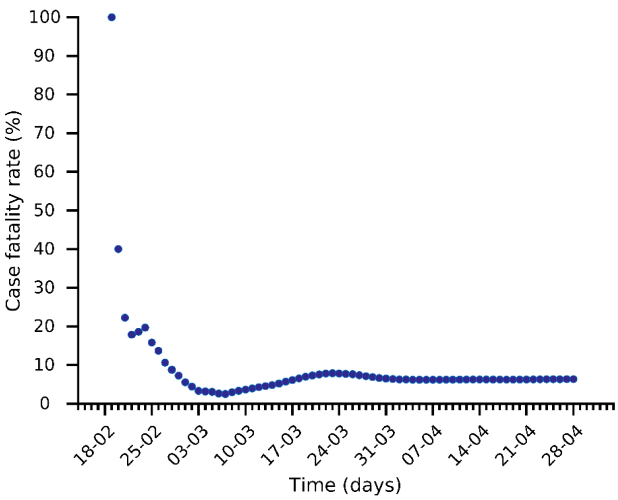




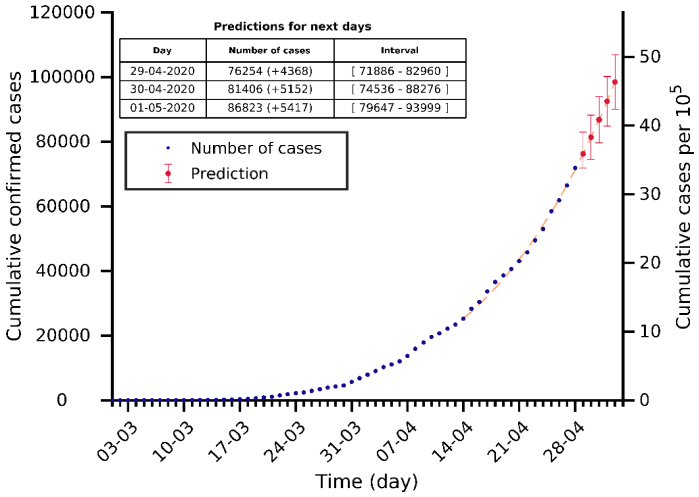


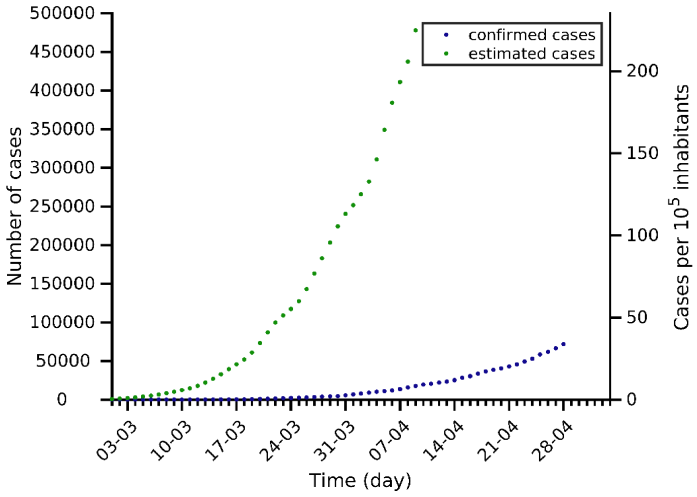


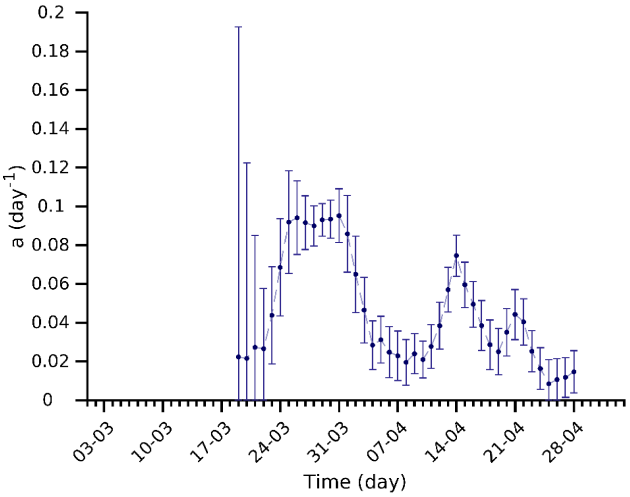


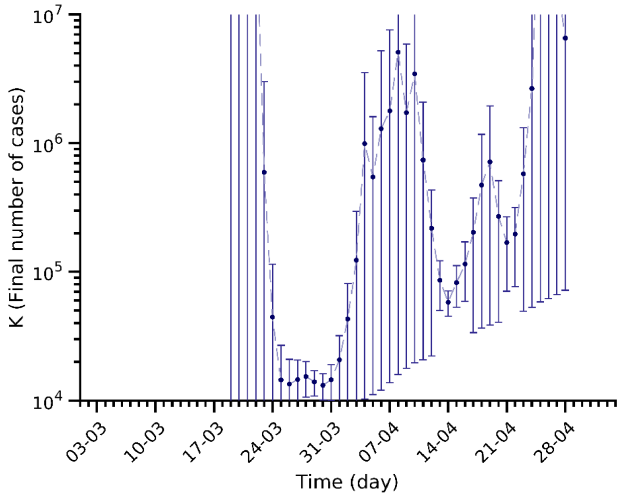


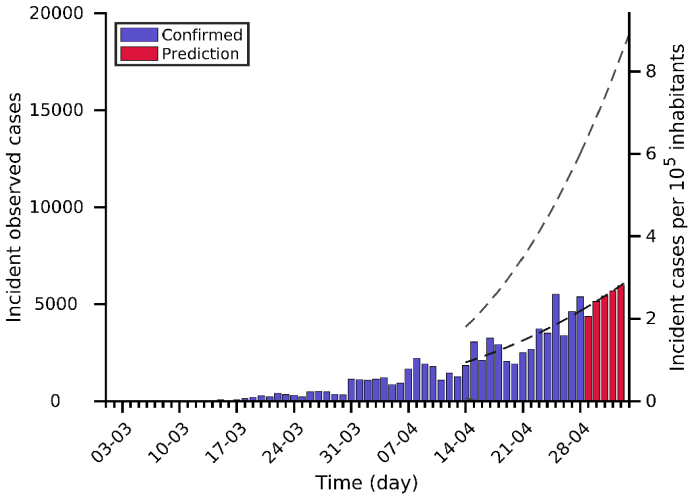
Brazil 28-04-2020. Population: 212.6M. Current cumulated incidence: $34/10^5$

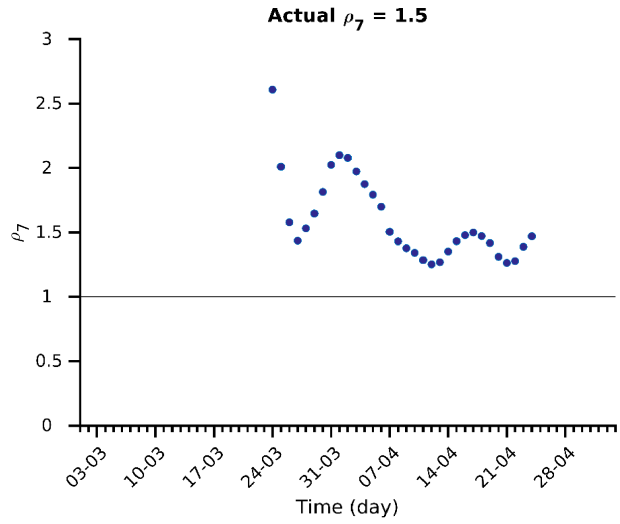


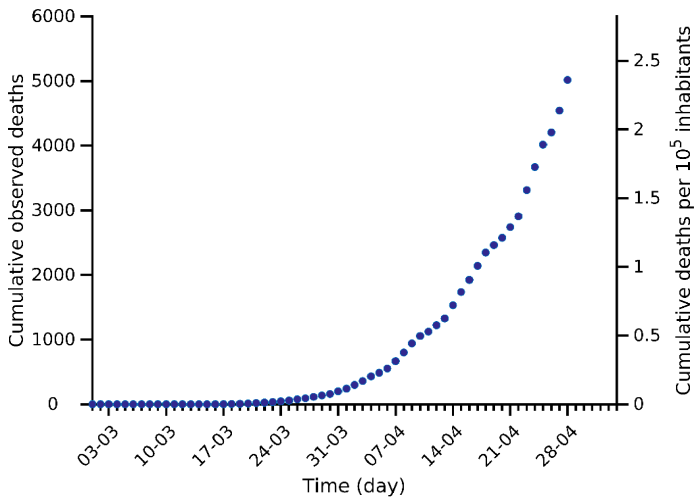


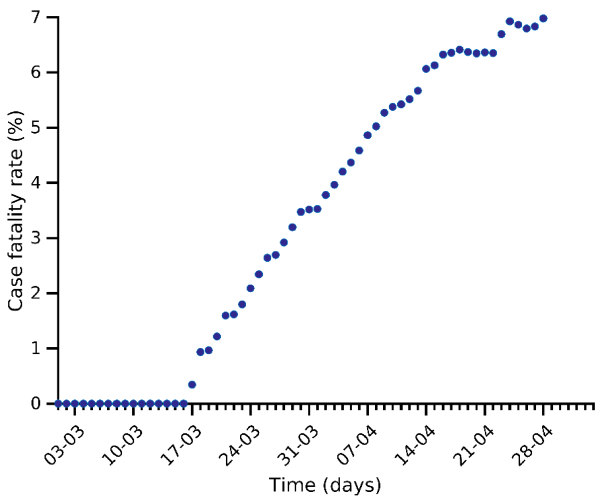




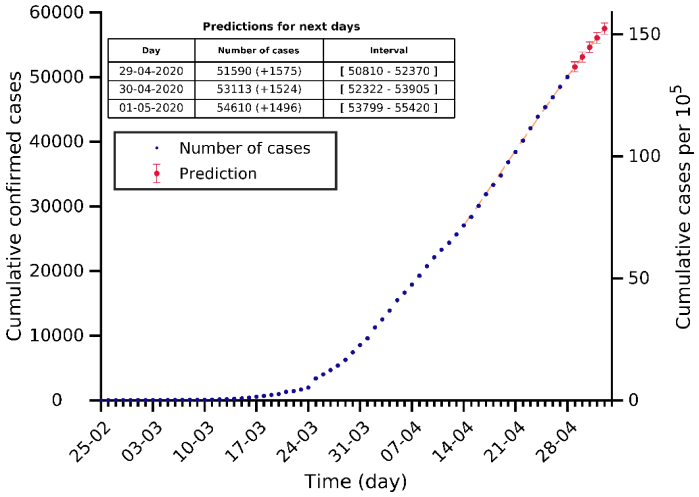


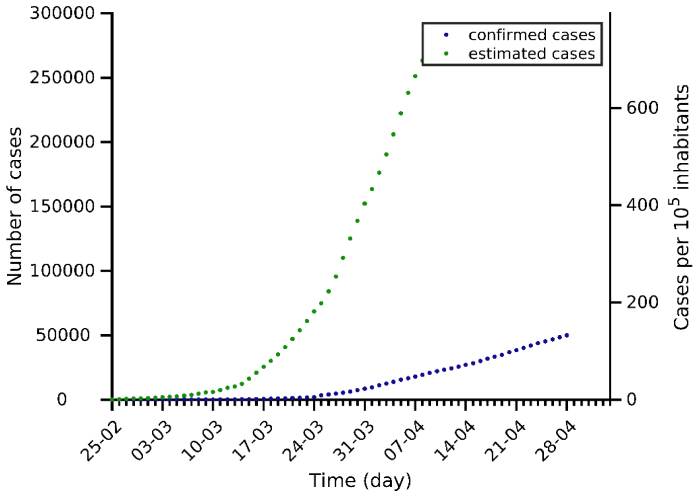


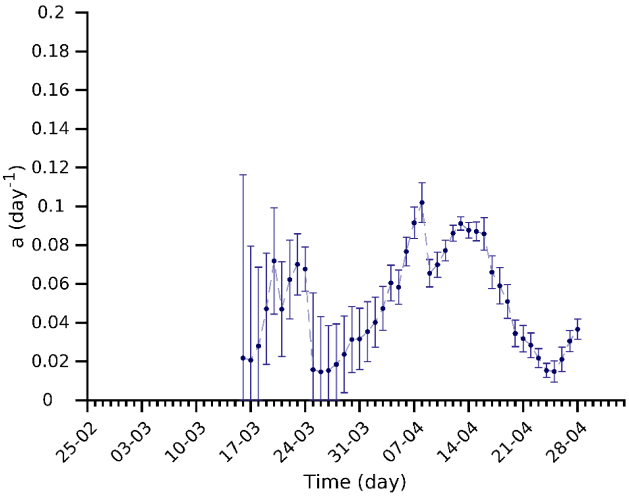


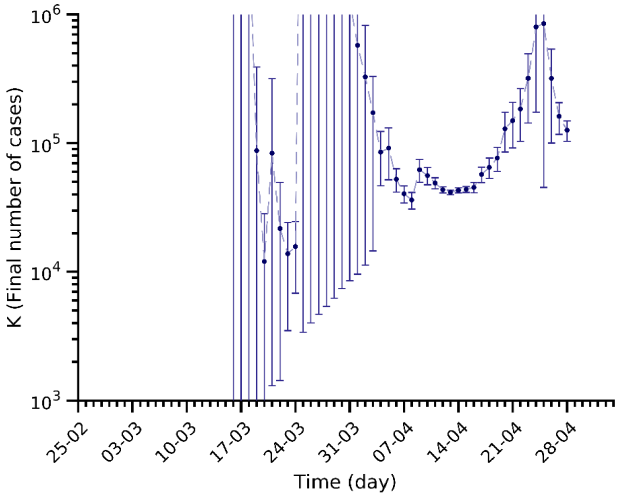


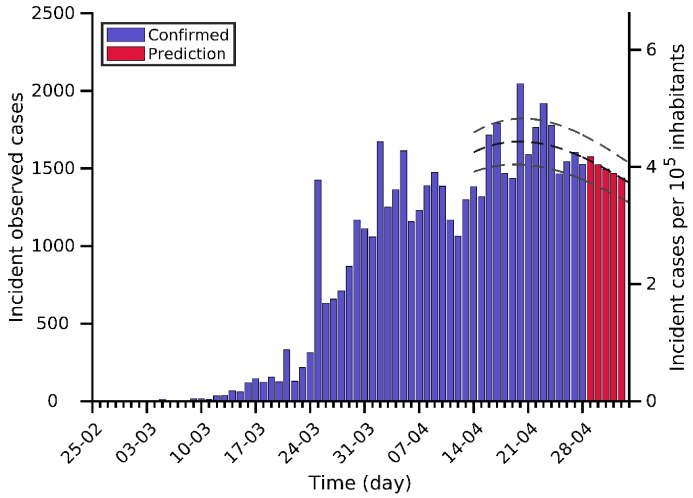
Canada 28-04-2020. Population: 37.7M. Current cumulated incidence: 133/10^5

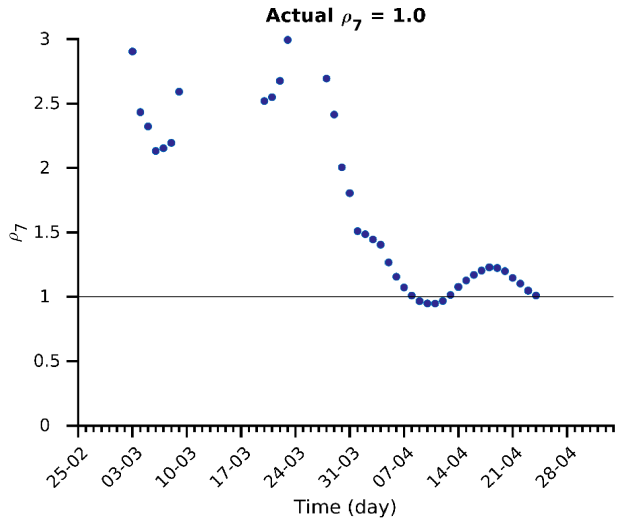


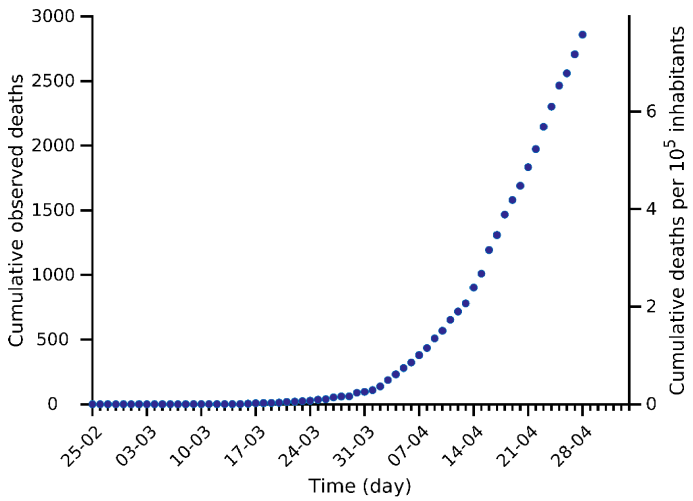


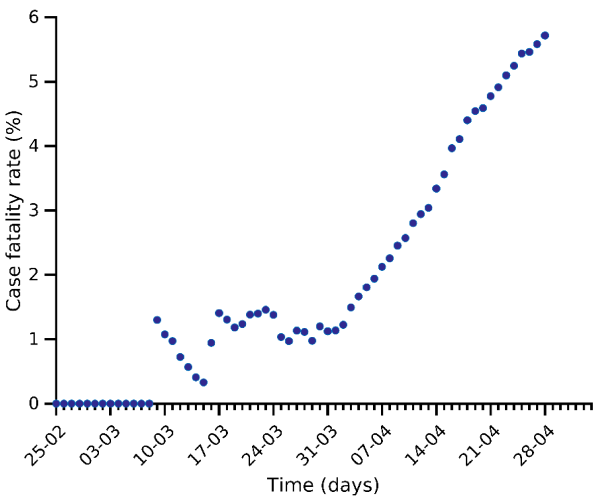




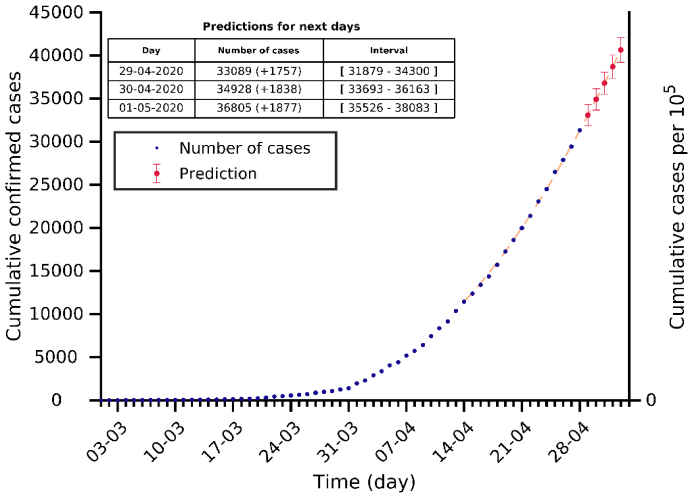


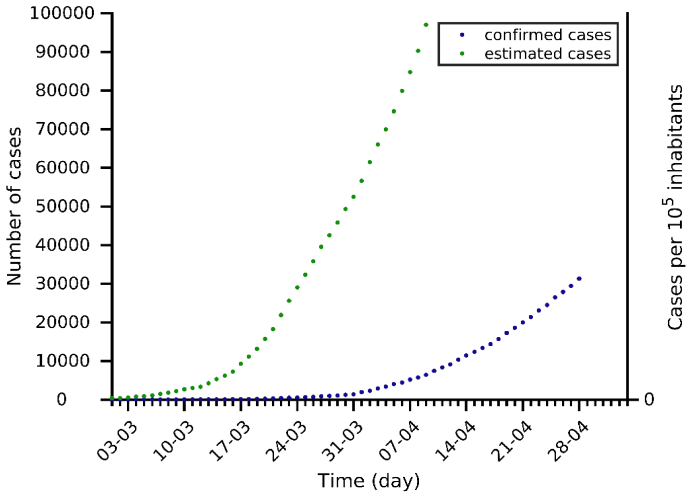


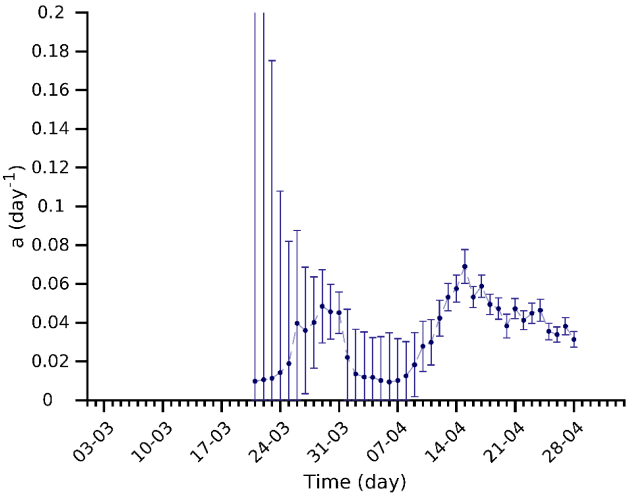


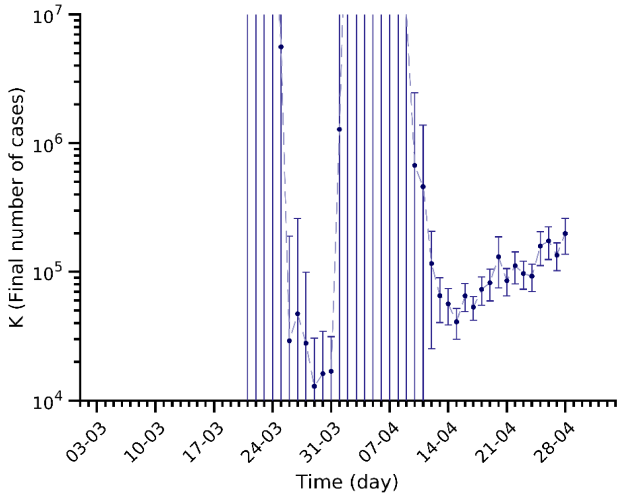


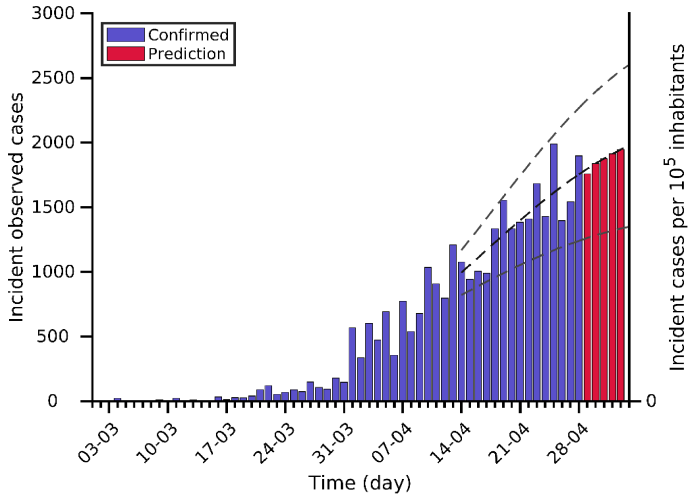
India 28-04-2020. Population: 1353000.0M. Current cumulated incidence: 0/10^5

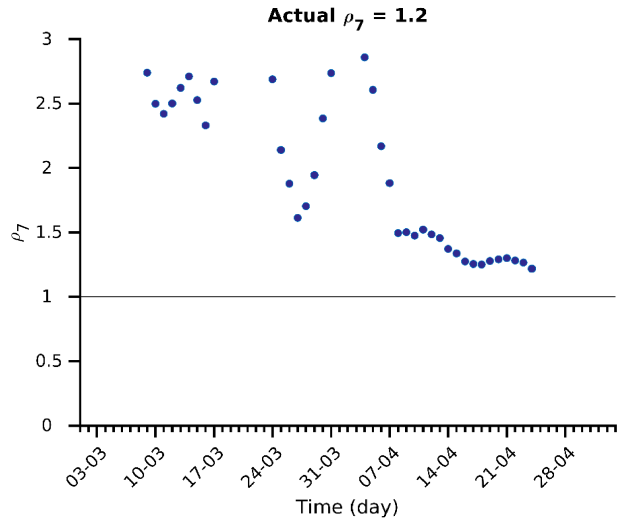


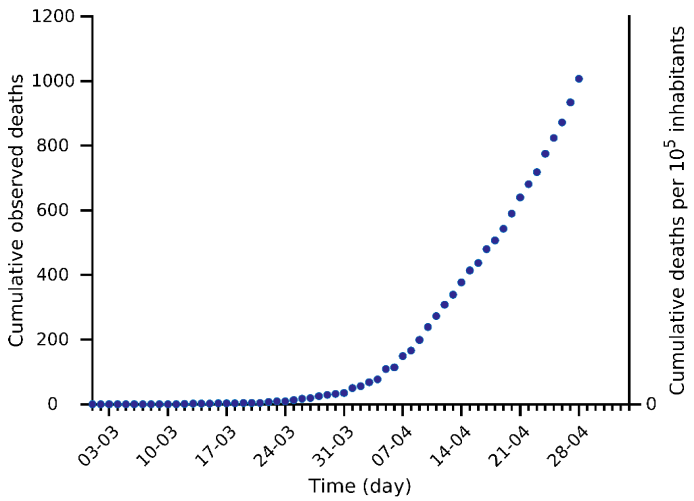


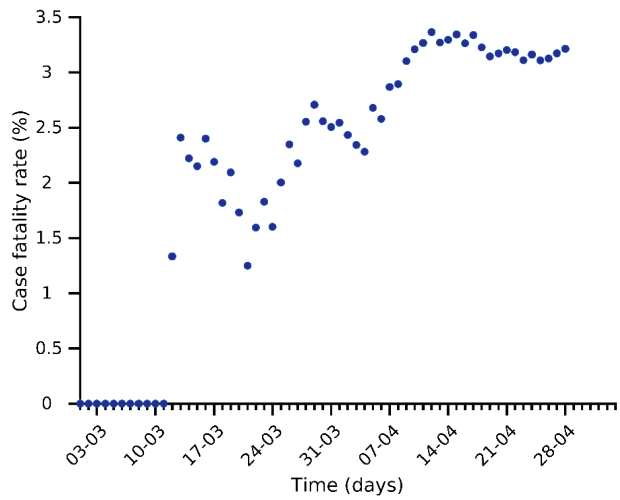




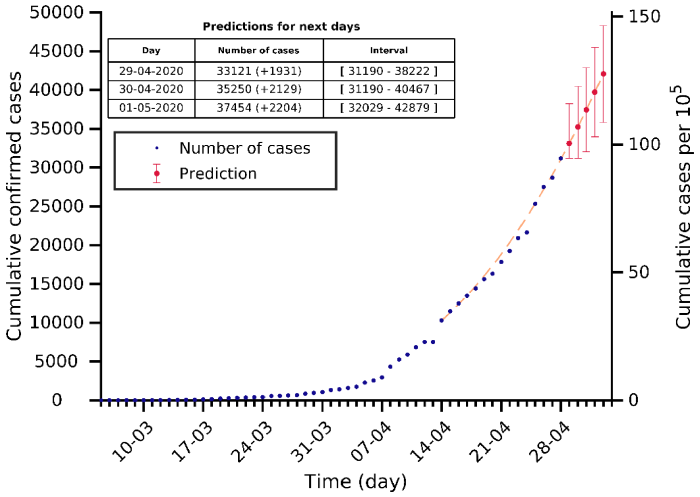


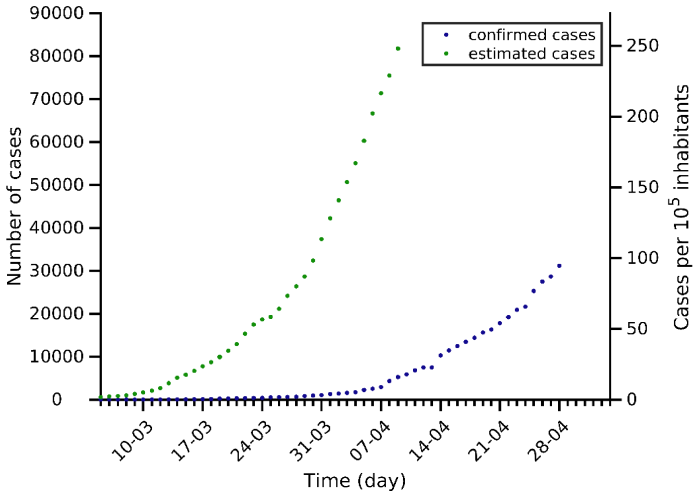


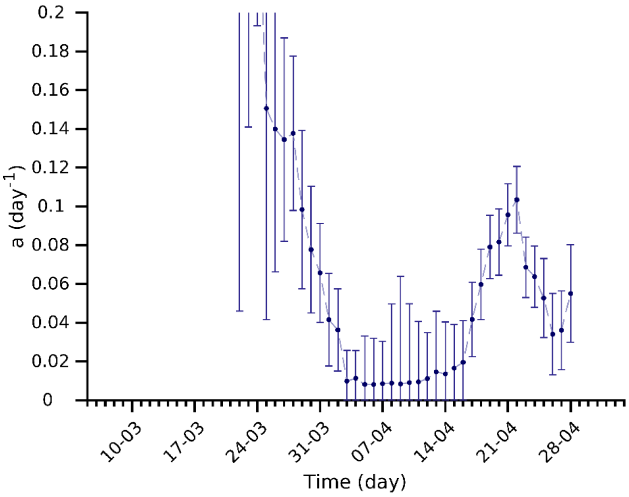


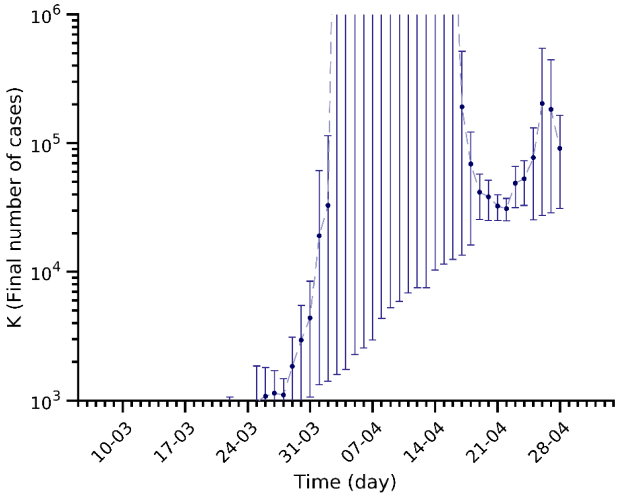


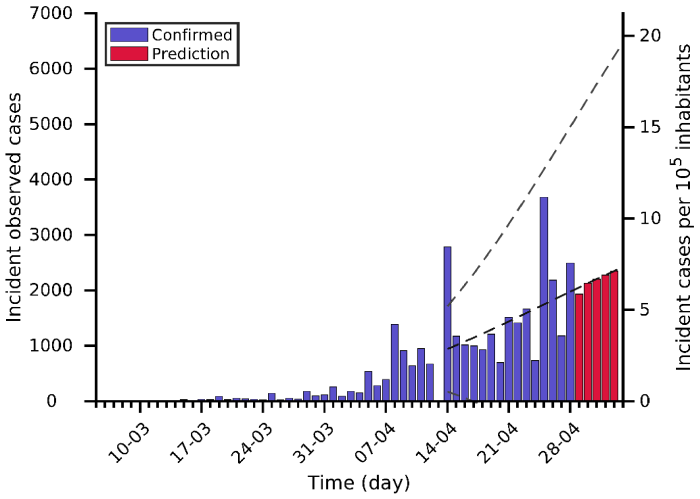
Peru 28-04-2020. Population: 33.0M. Current cumulated incidence: 95/10^5

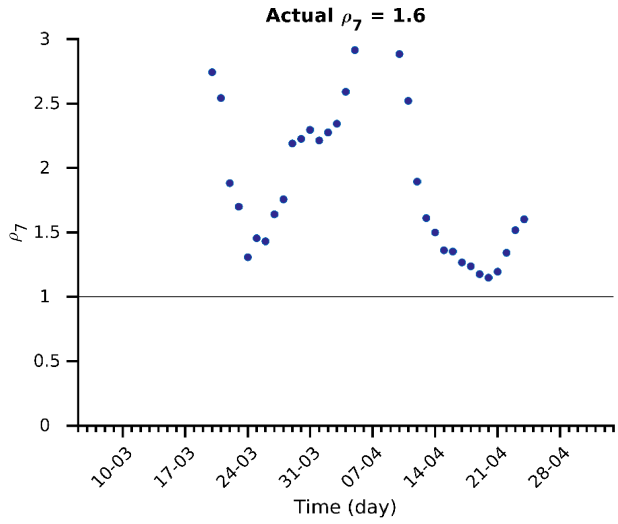


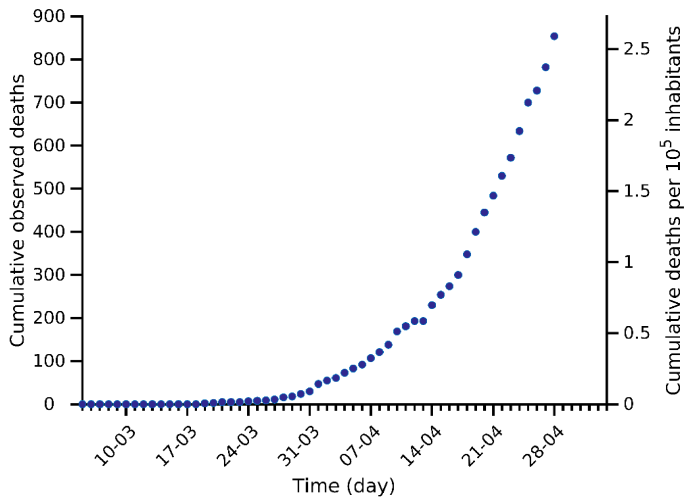


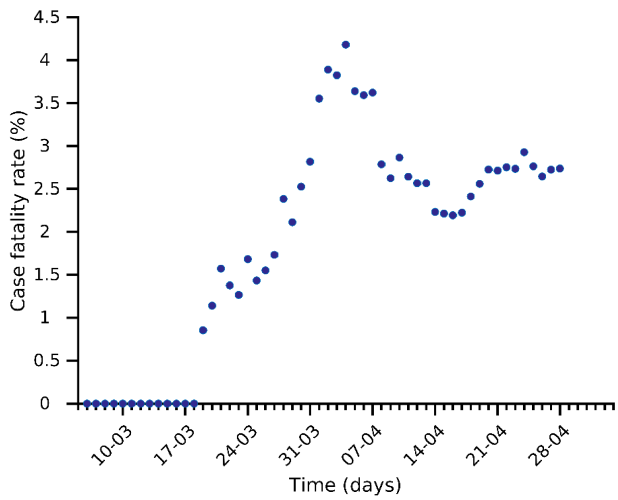




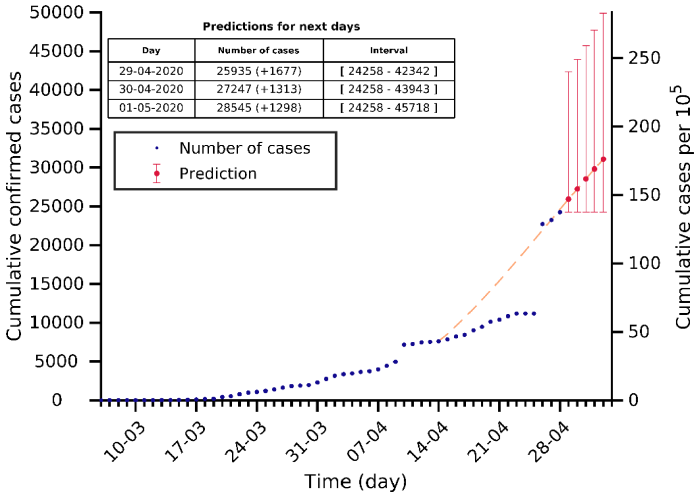


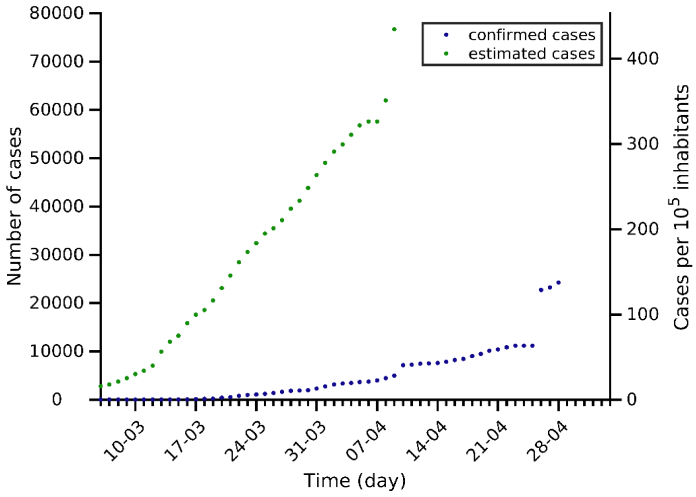


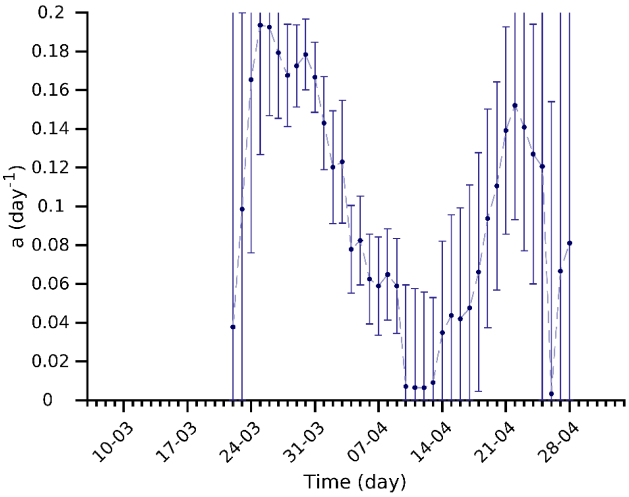


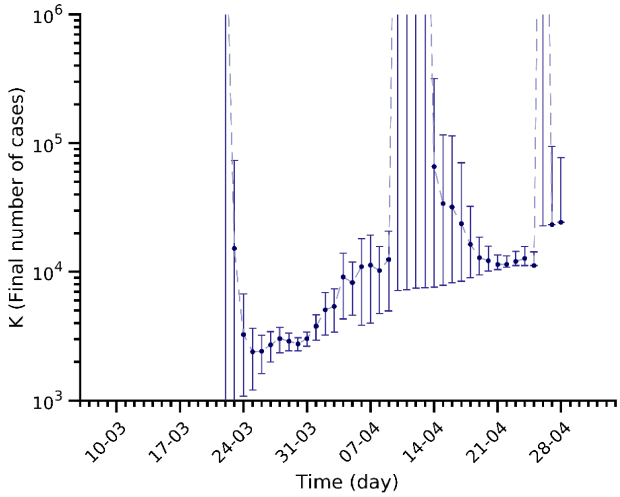


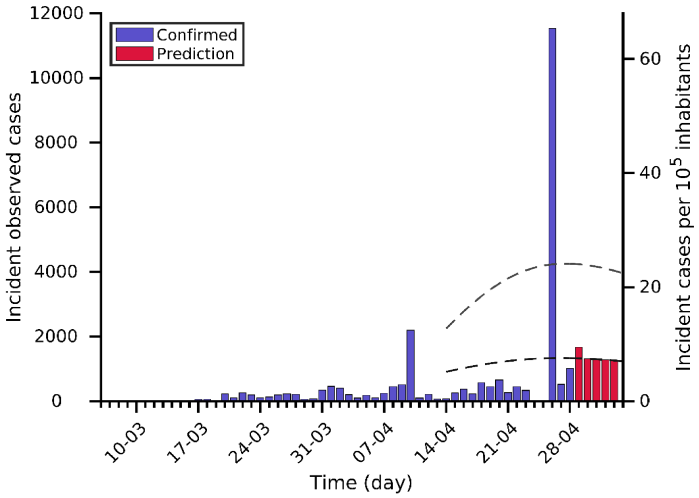
Ecuador 28-04-2020. Population: 17.6M. Current cumulated incidence: 137/10^5

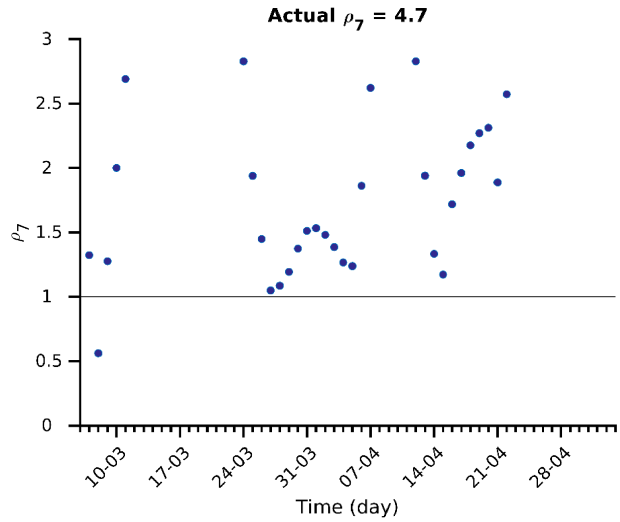


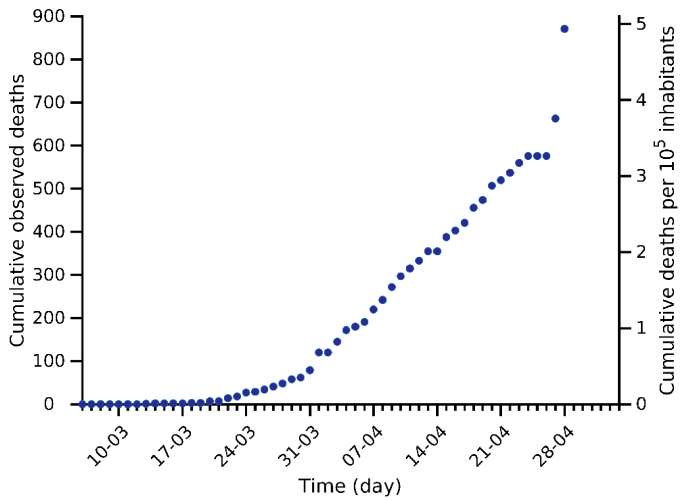


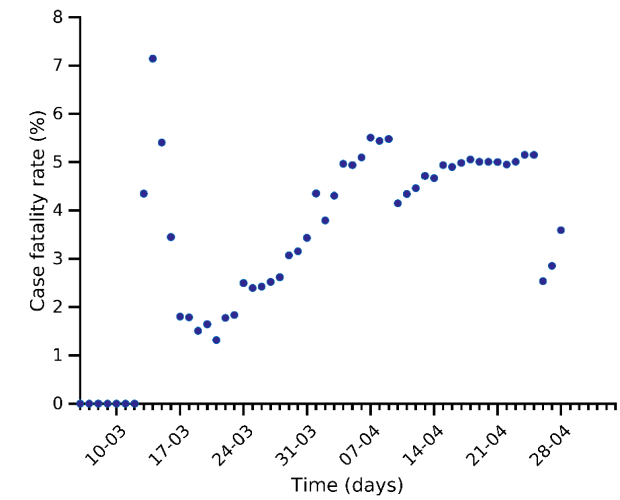




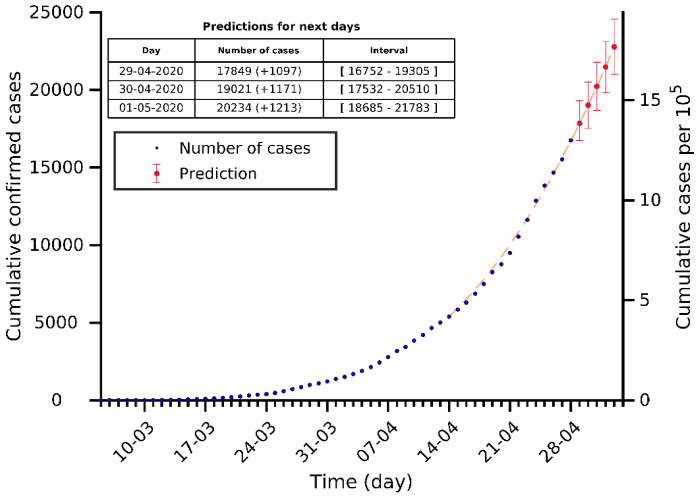


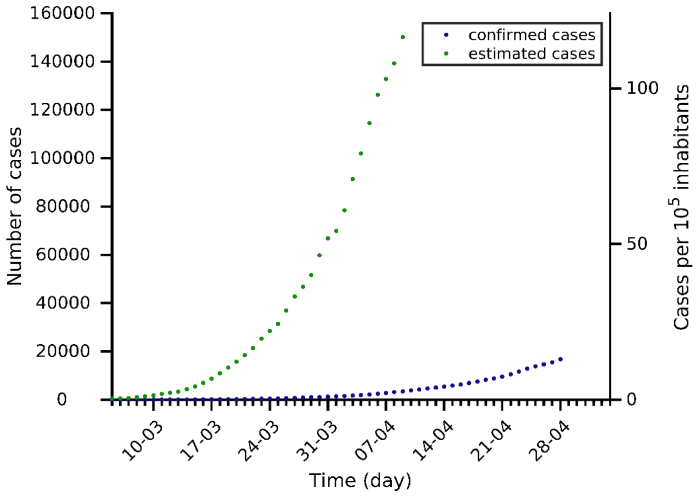


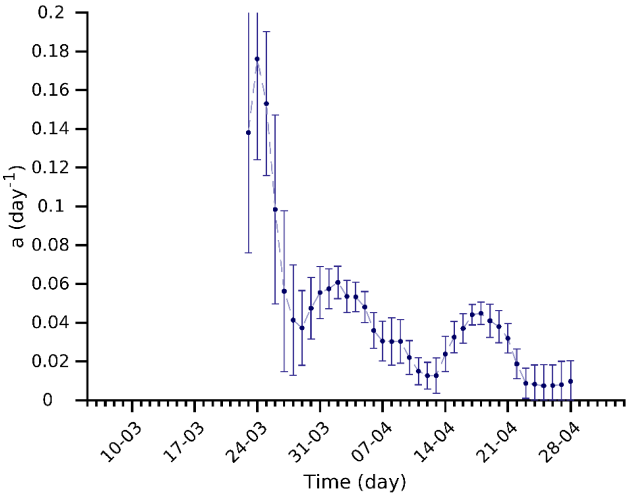


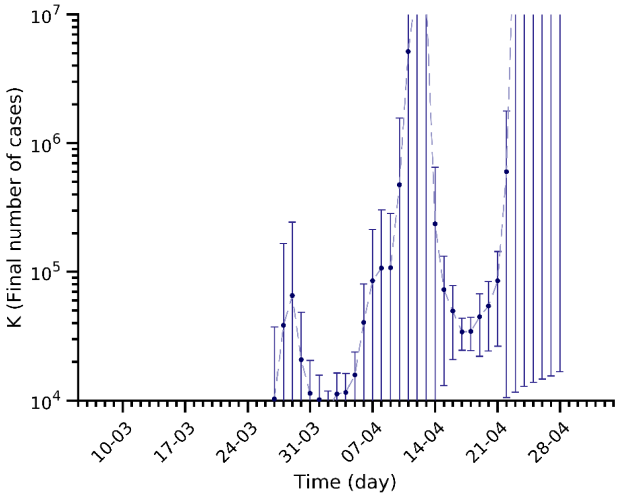


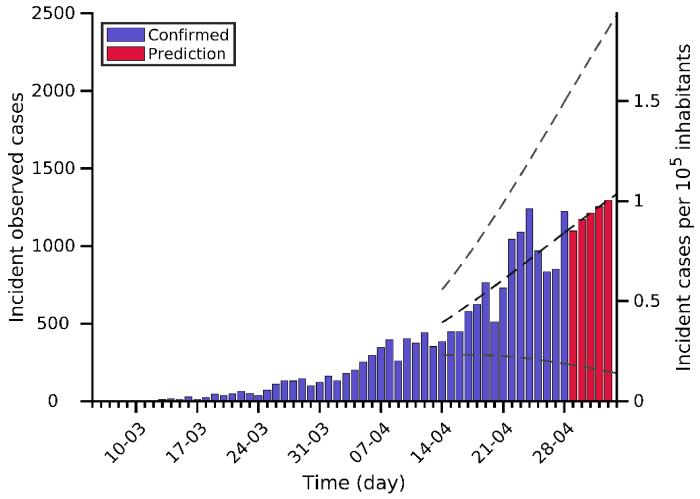
Mexico 28-04-2020. Population: 128.9M. Current cumulated incidence: 13/10^5

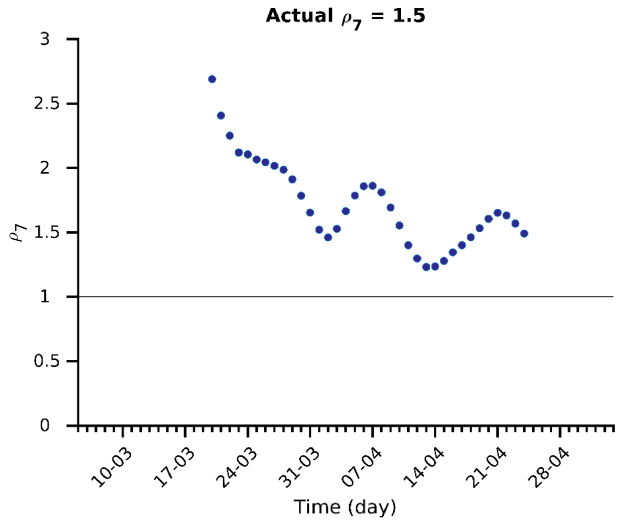


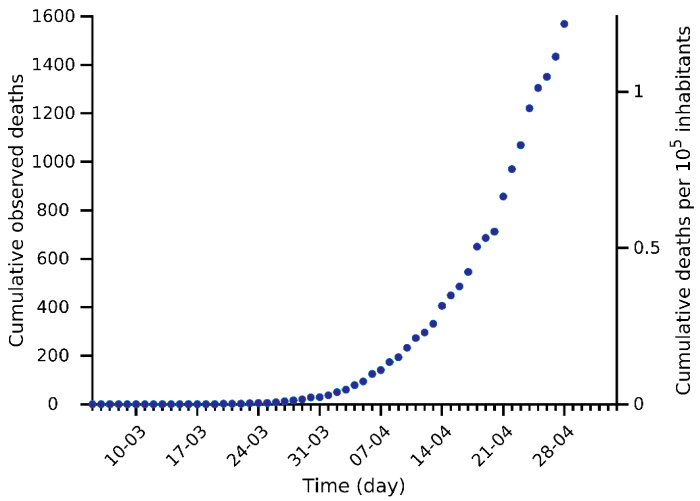


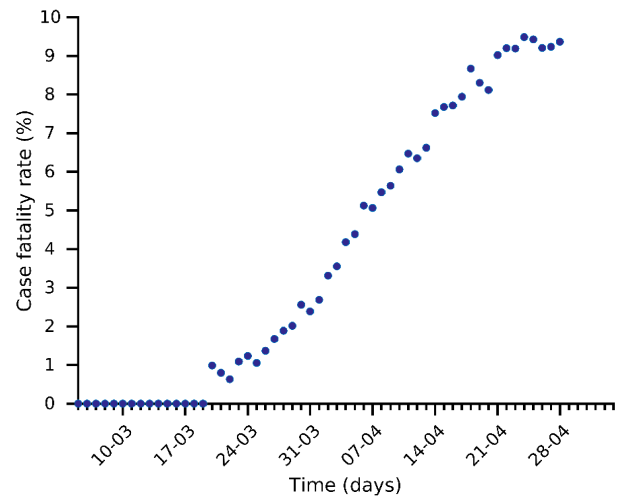




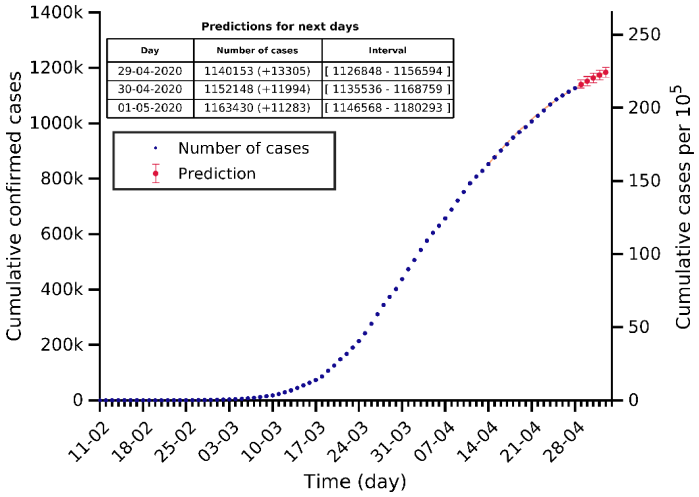


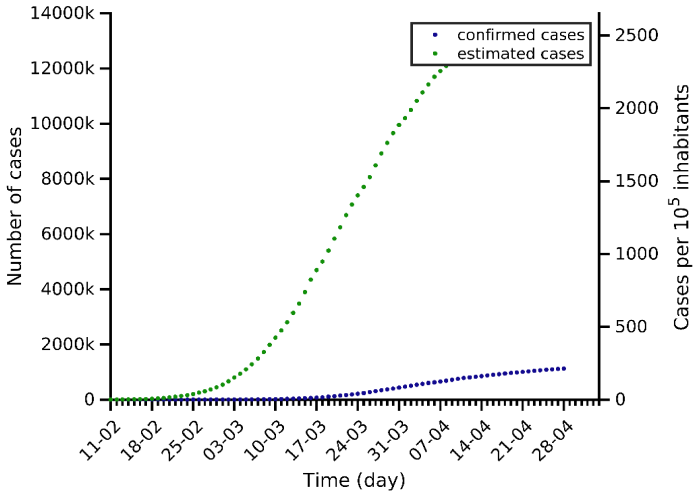


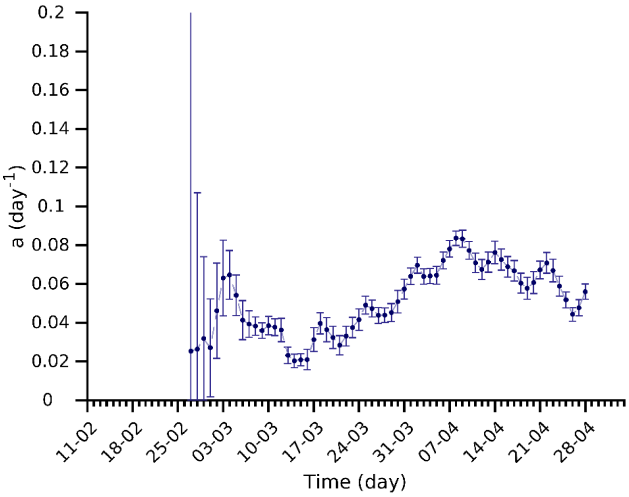


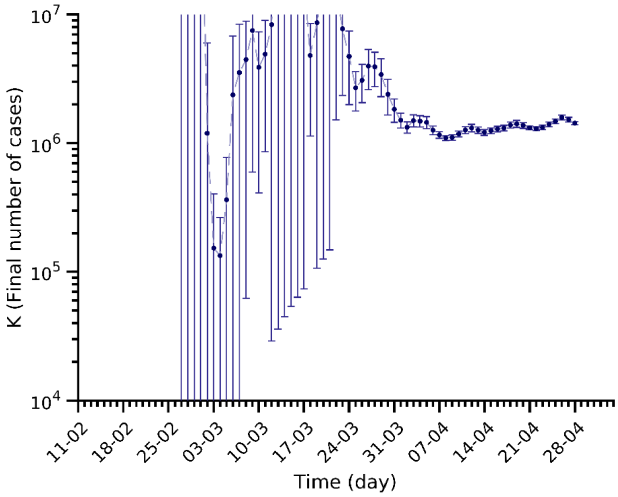


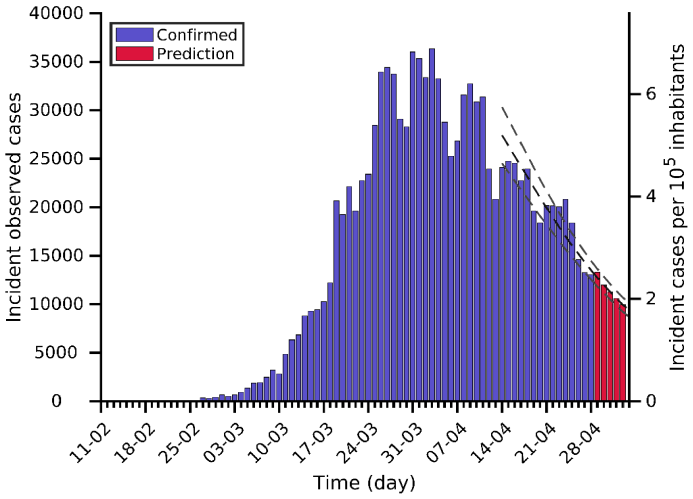
Israel 28-04-2020. Population: 8.7M. Current cumulated incidence: $180/10^5$

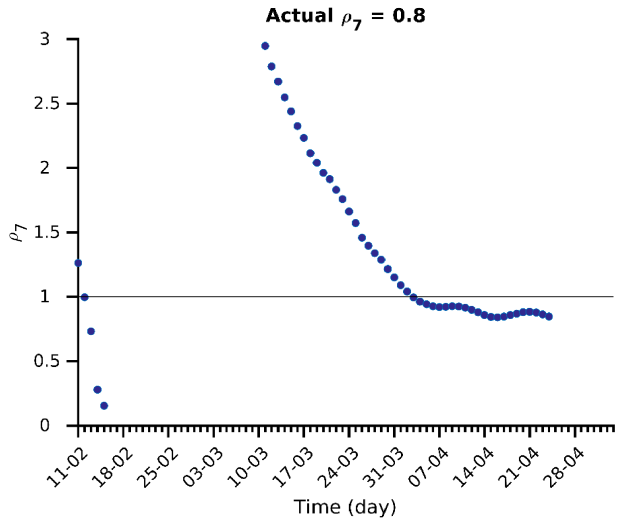


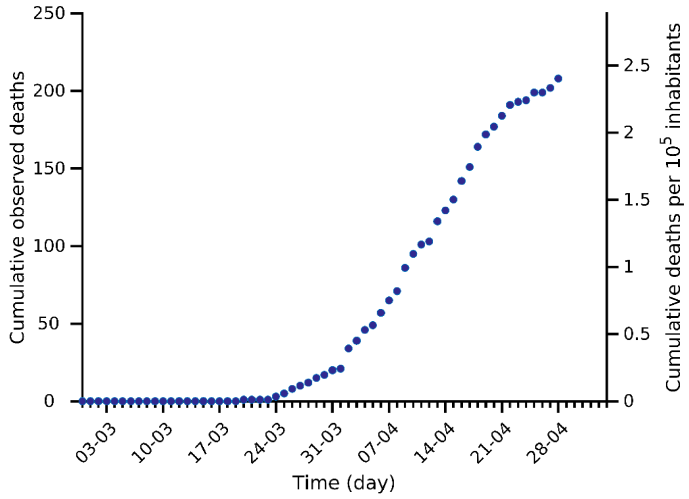


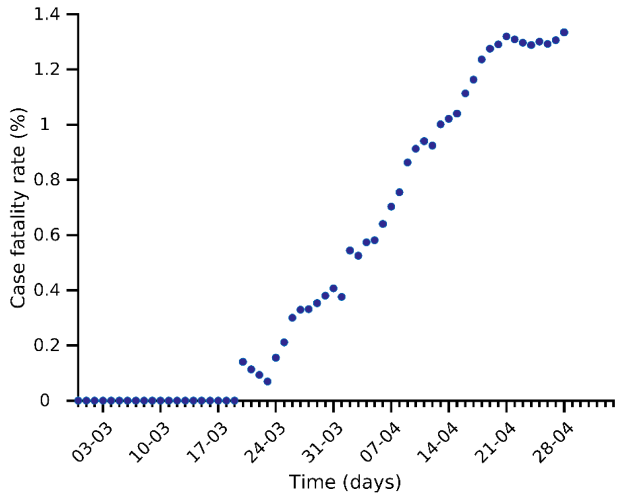




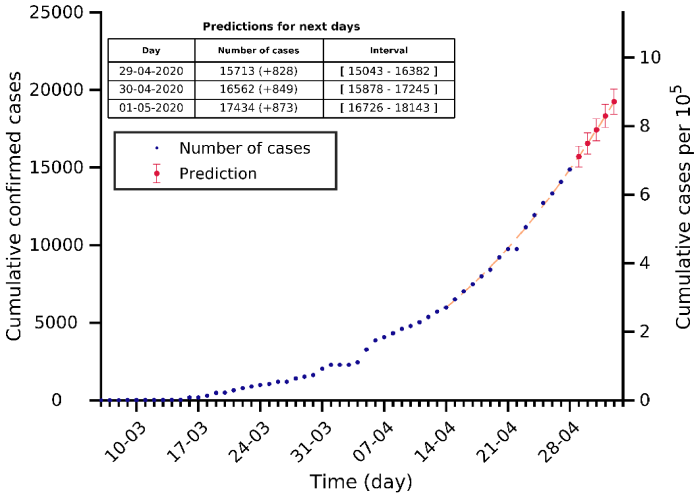


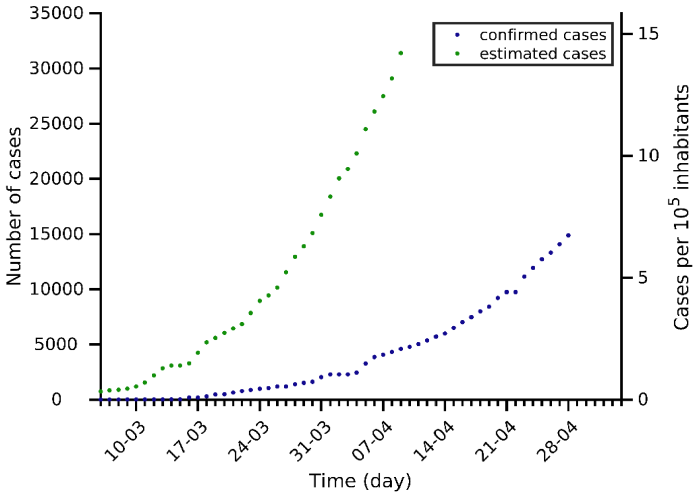


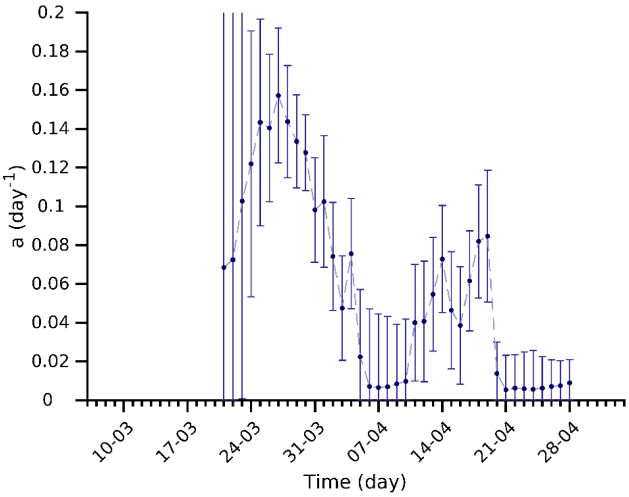


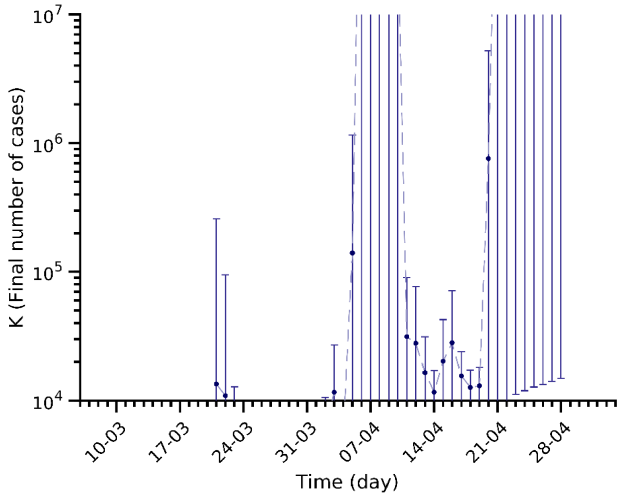


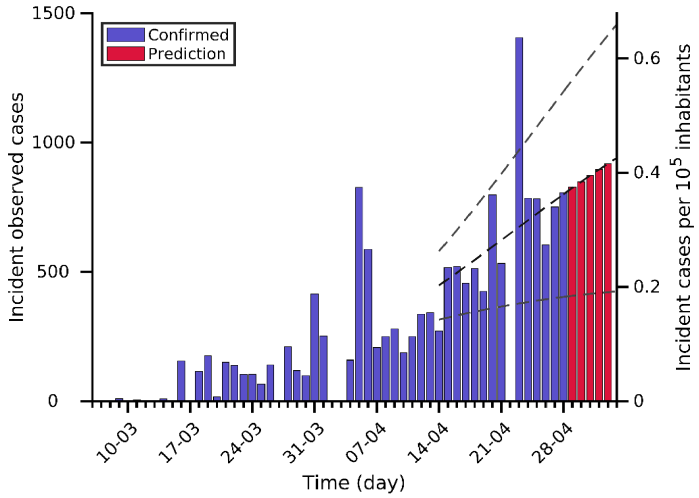
Pakistan 28-04-2020. Population: 220.9M. Current cumulated incidence: $7/10^5$

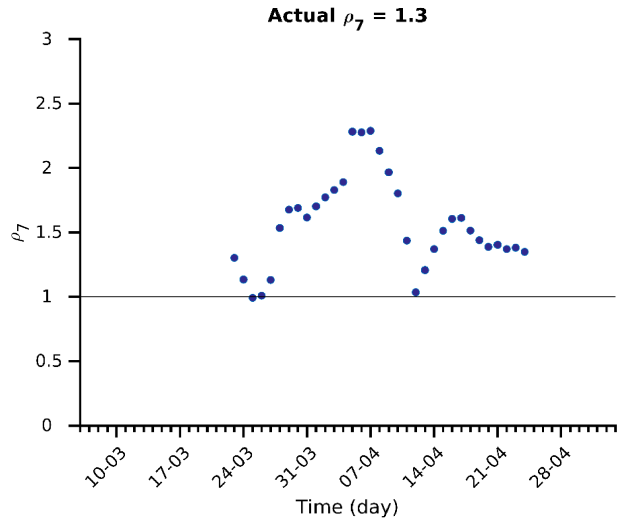


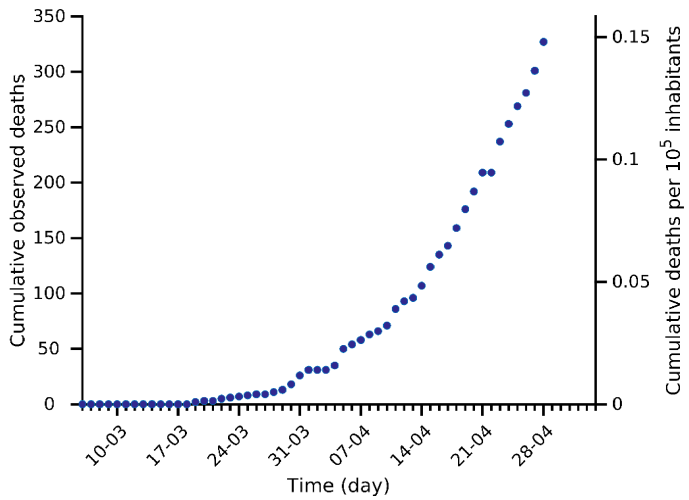


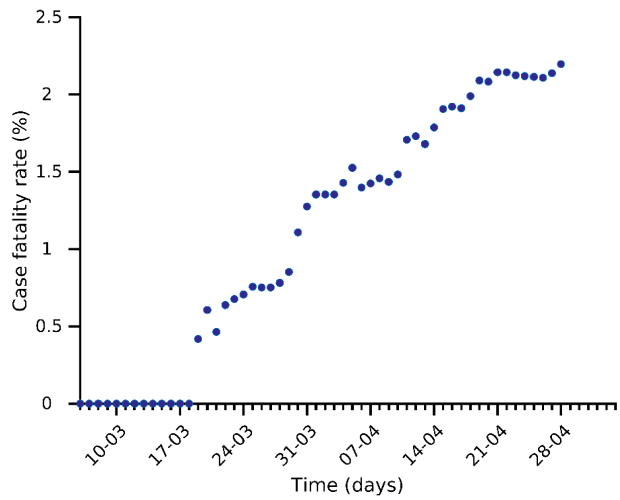




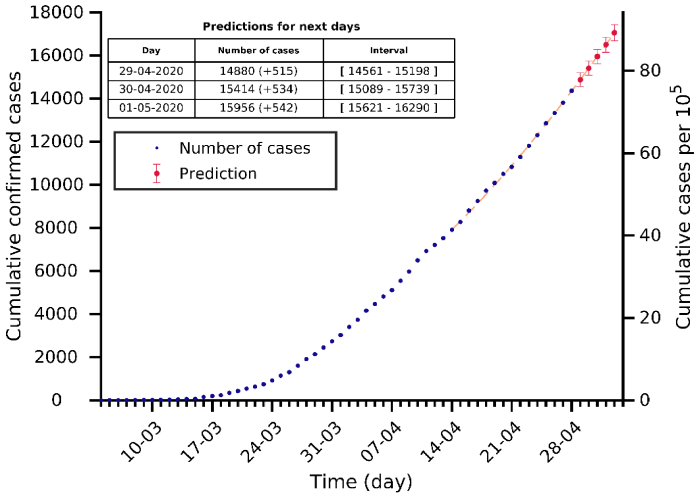


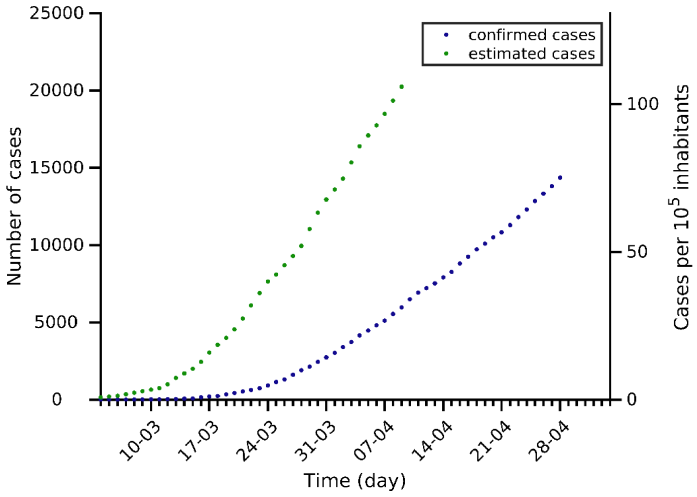


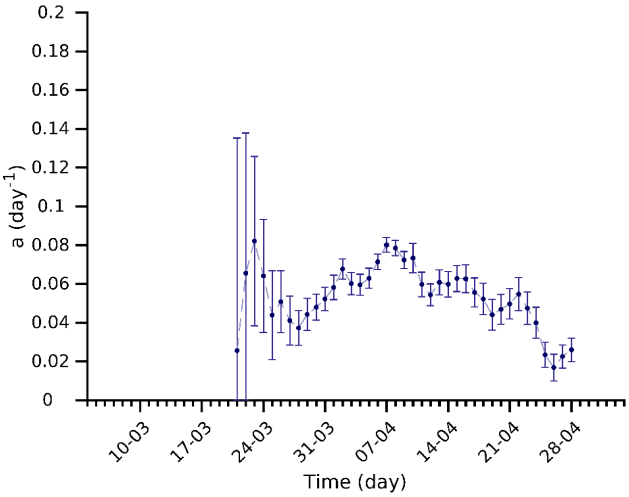


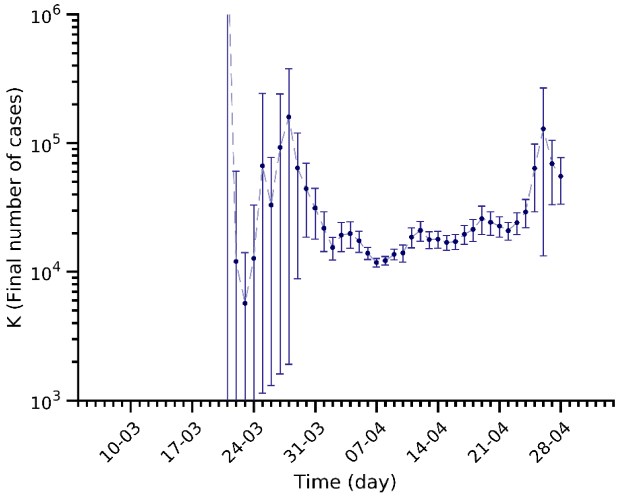


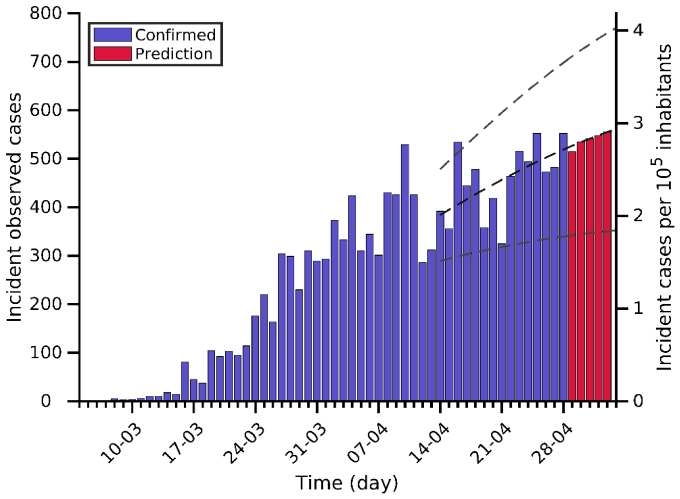
Chile 28-04-2020. Population: 19.1M. Current cumulated incidence: 75/10^5

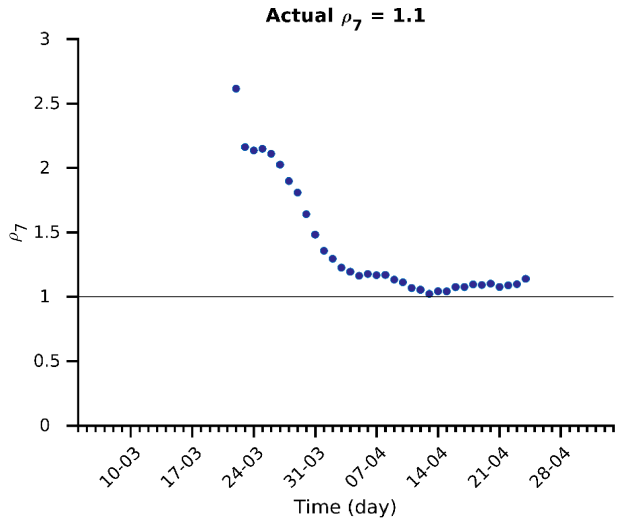


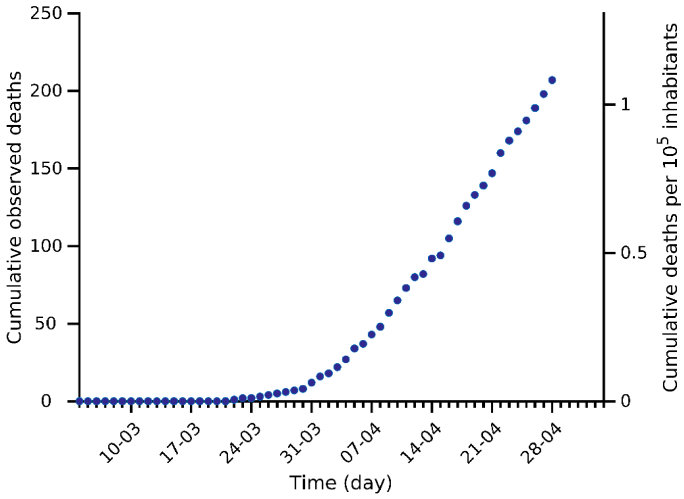


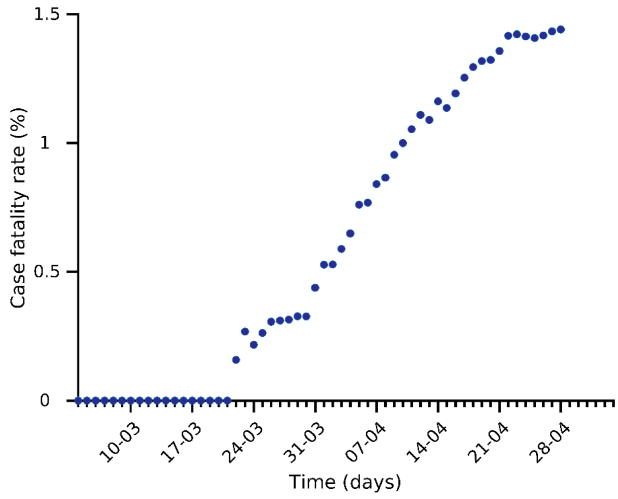




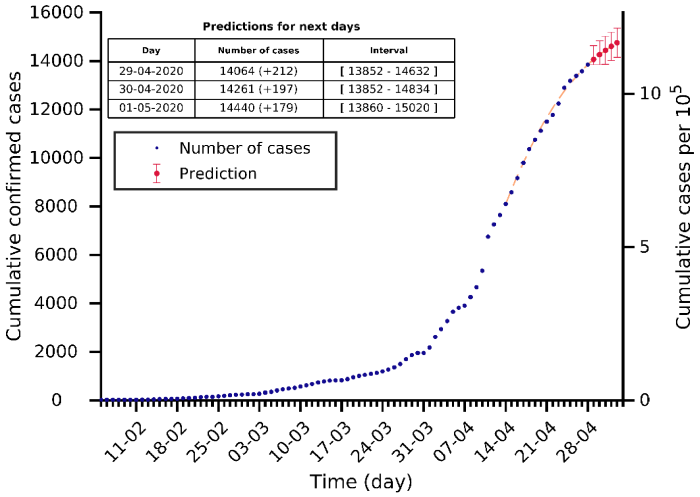


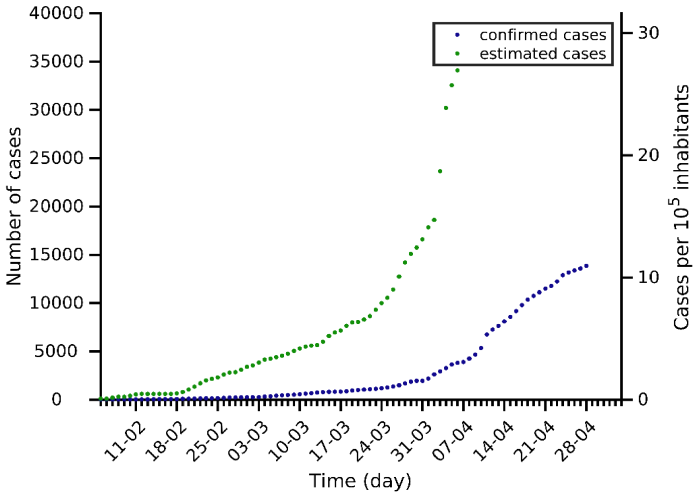


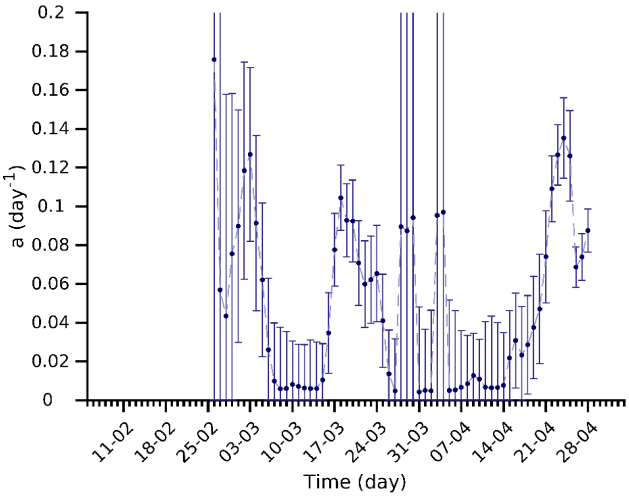


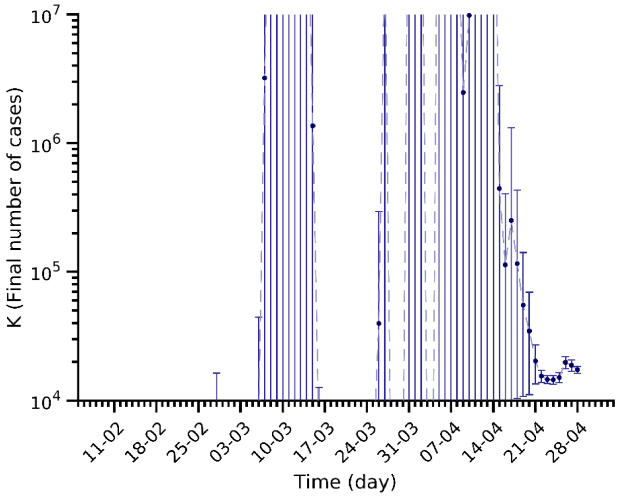


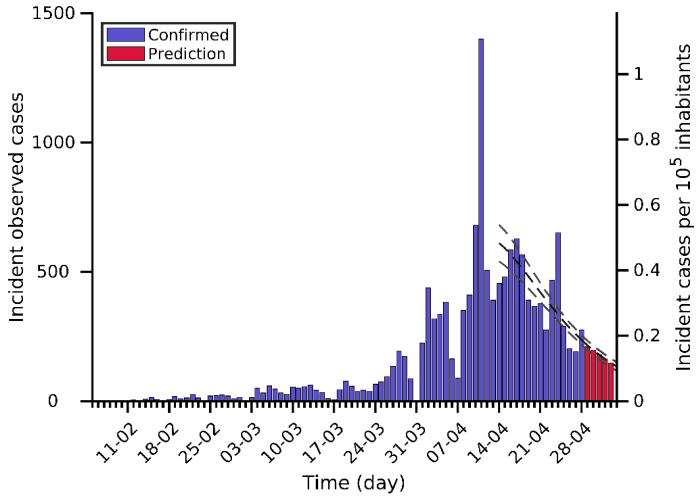
Japan 28-04-2020. Population: 126.5M. Current cumulated incidence: 11/10^5

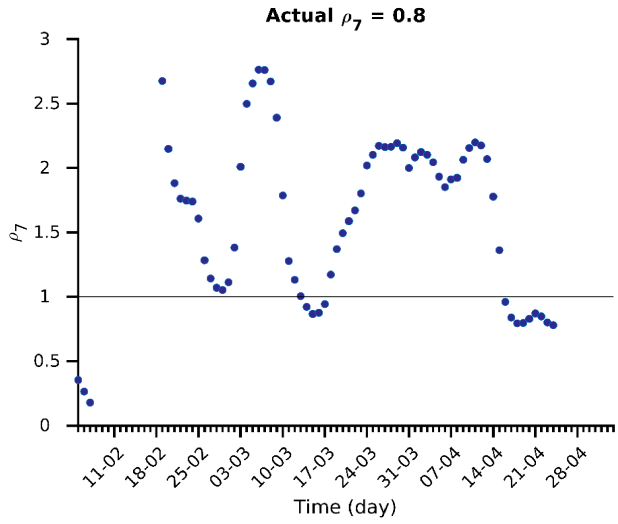


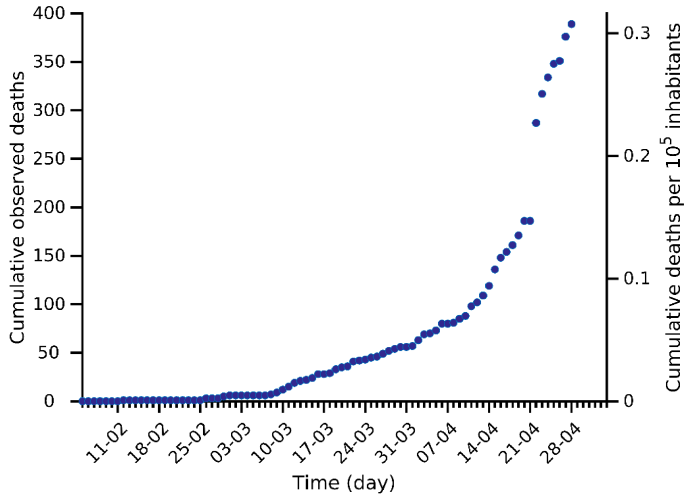


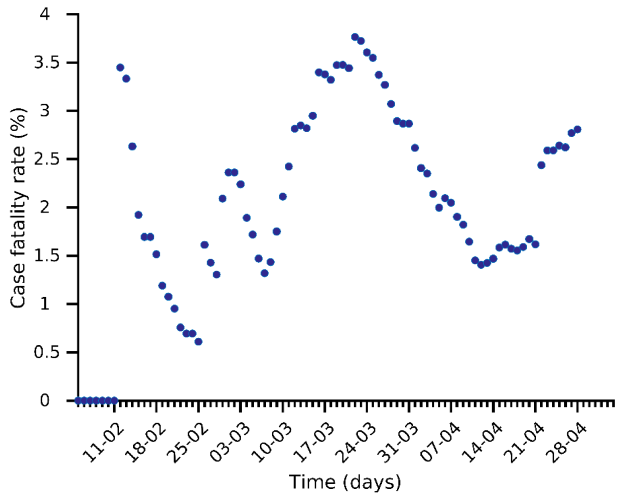




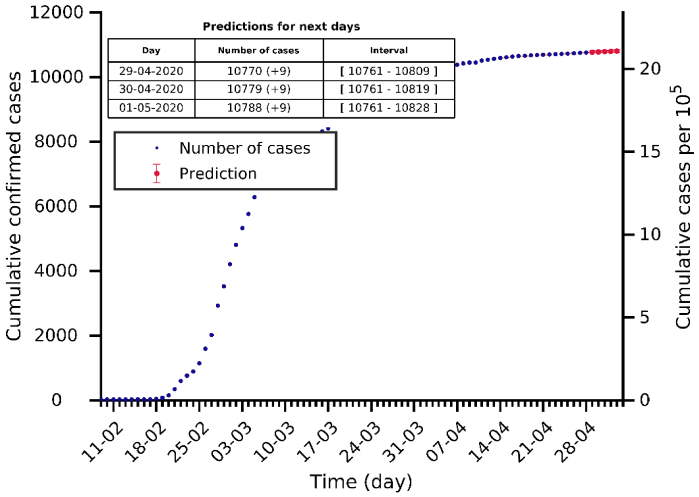


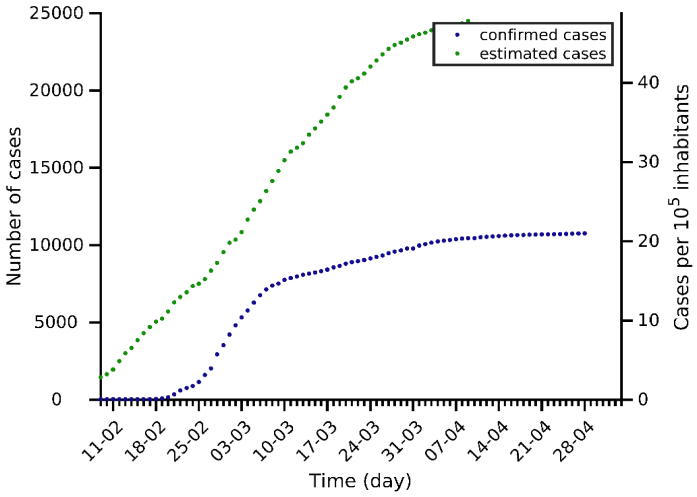


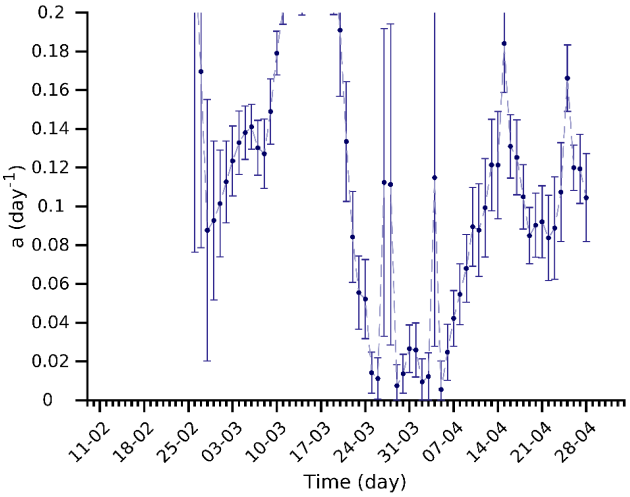


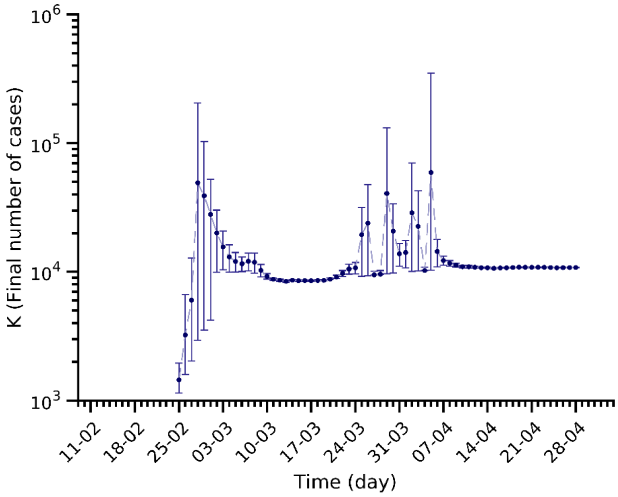


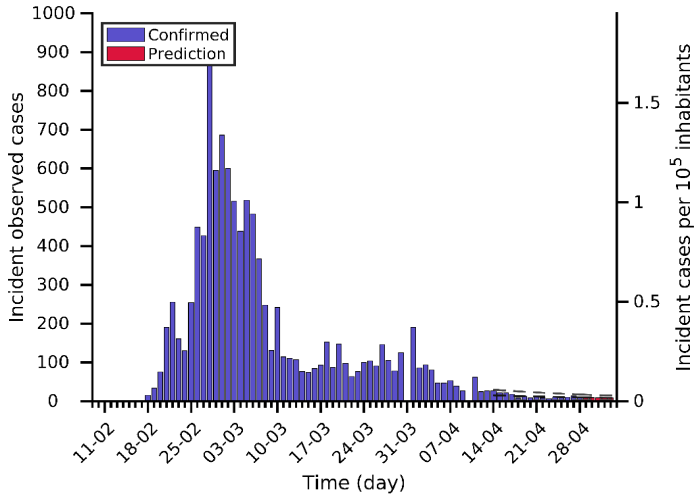
South Korea 28-04-2020. Population: 51.3M. Current cumulated incidence: 21/10^5

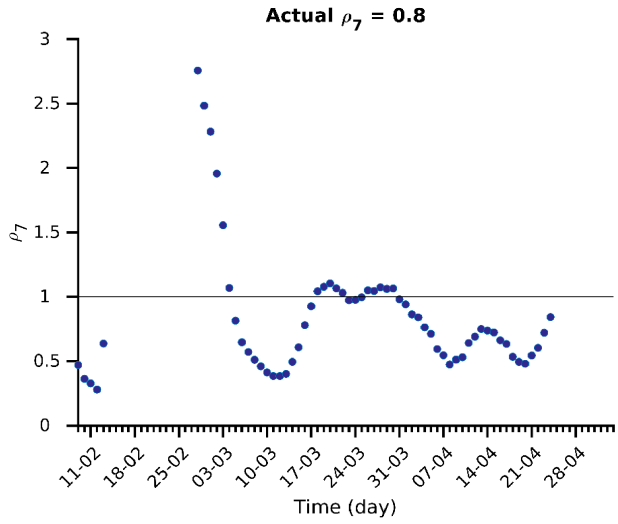


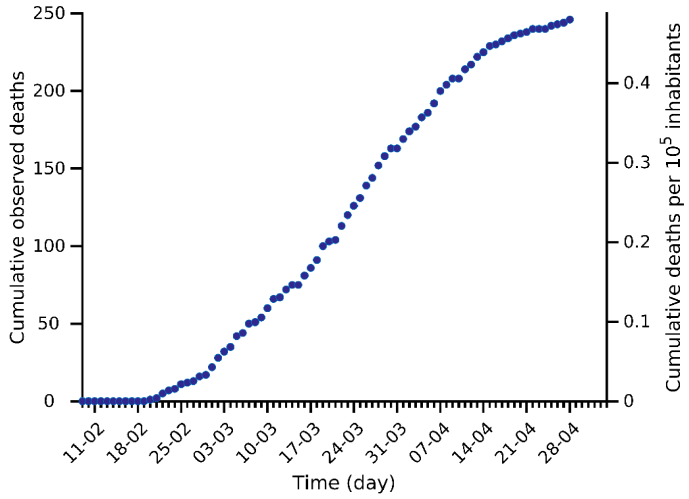


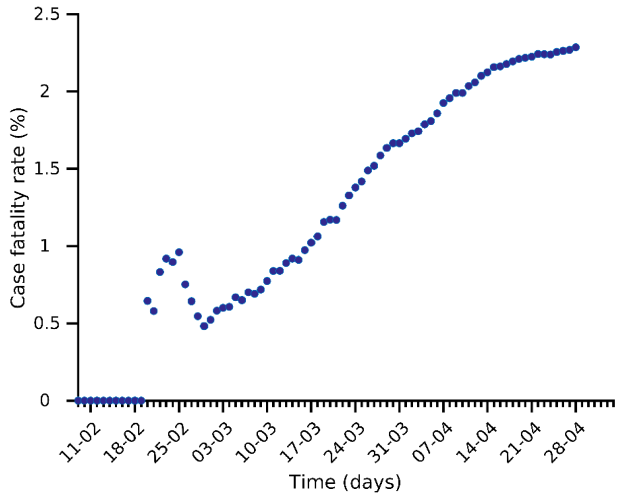




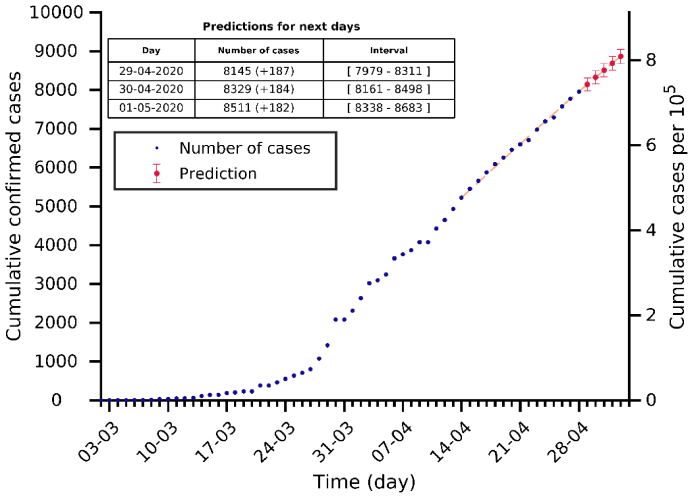


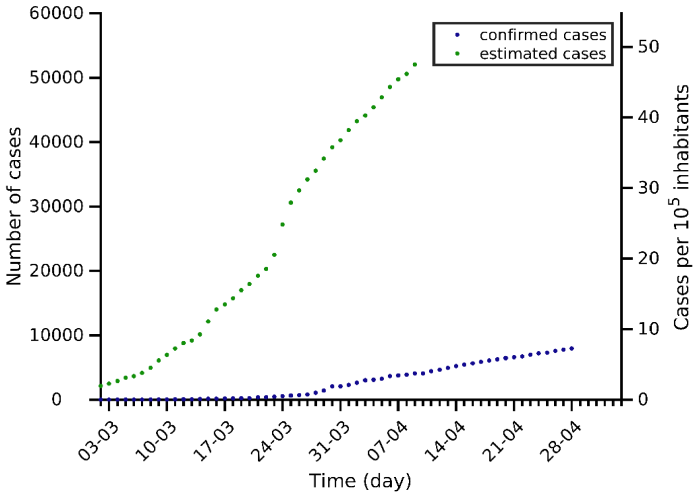


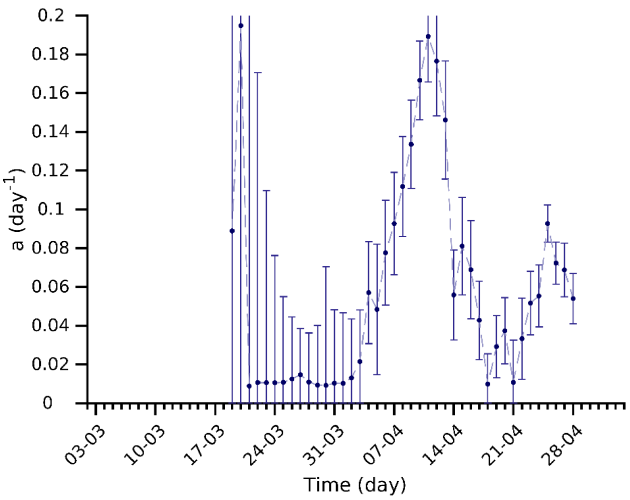


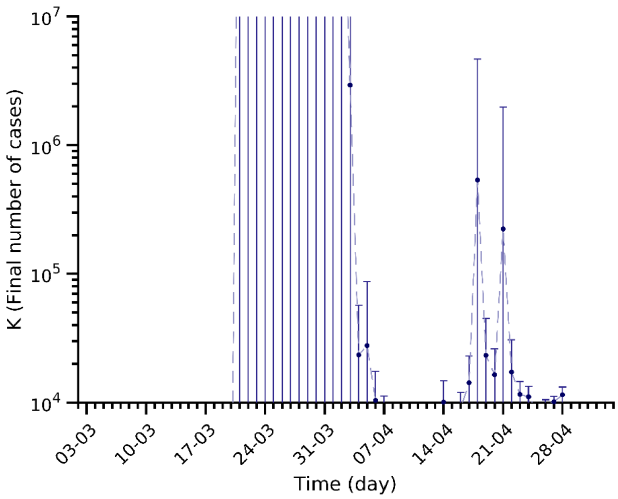


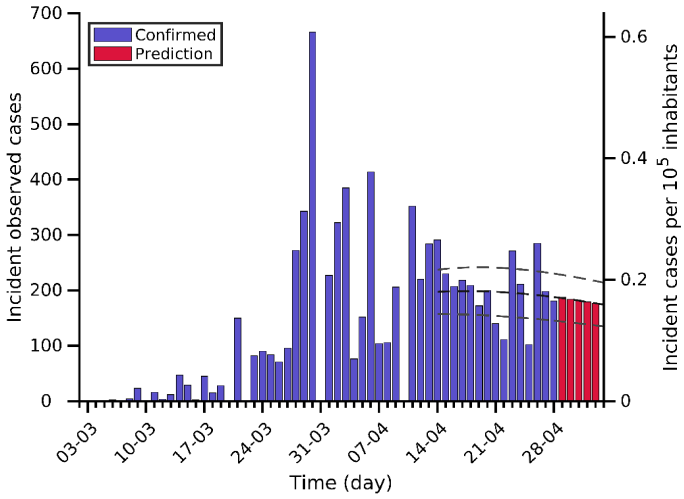
Philippines 28-04-2020. Population: 109.6M. Current cumulated incidence: 7/10^5

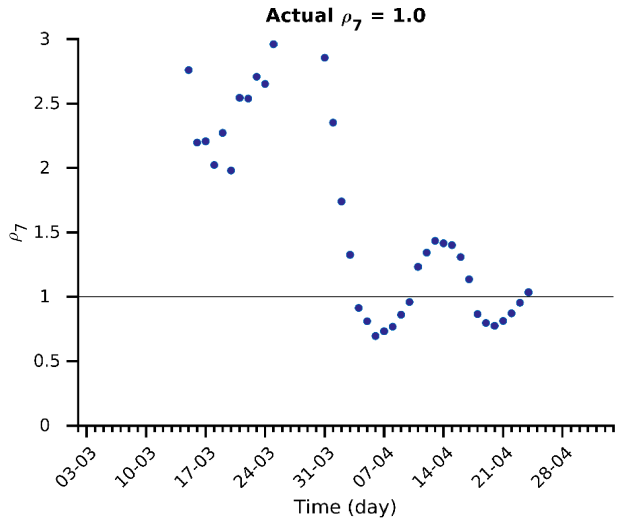


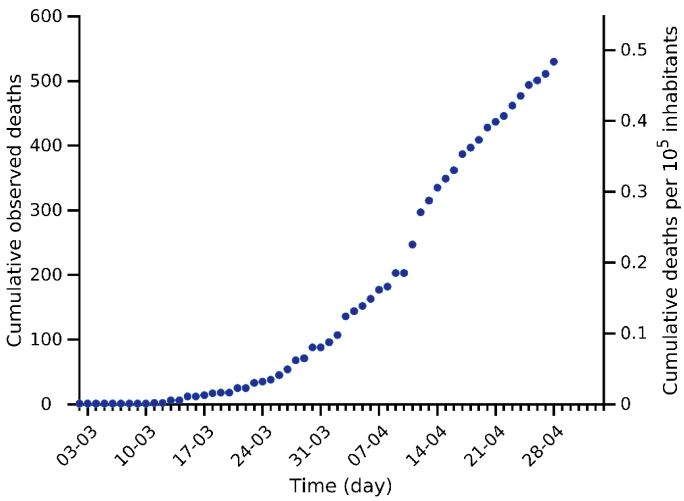


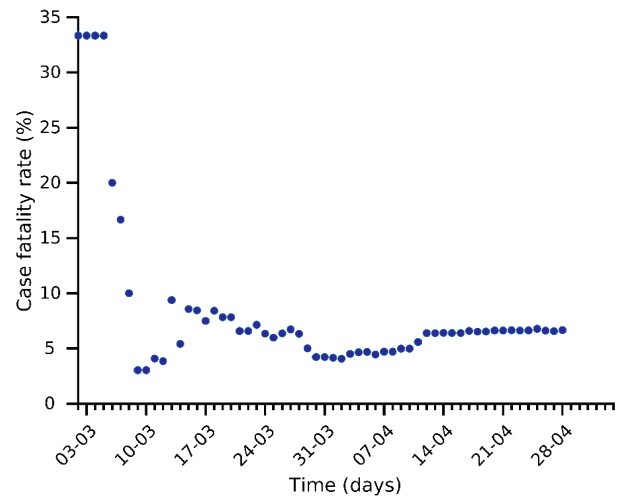




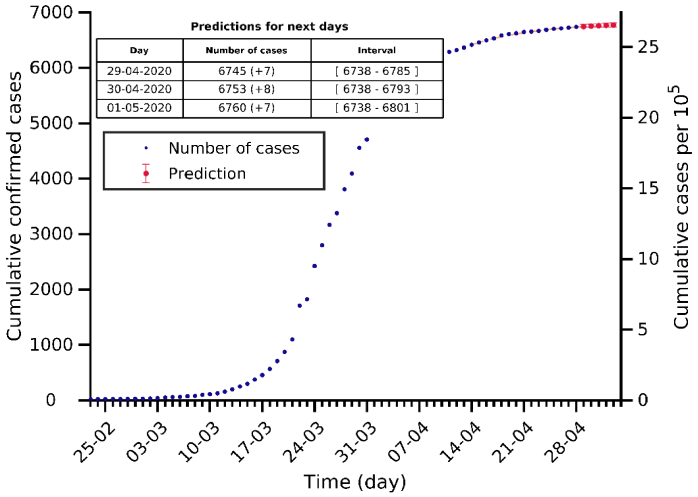


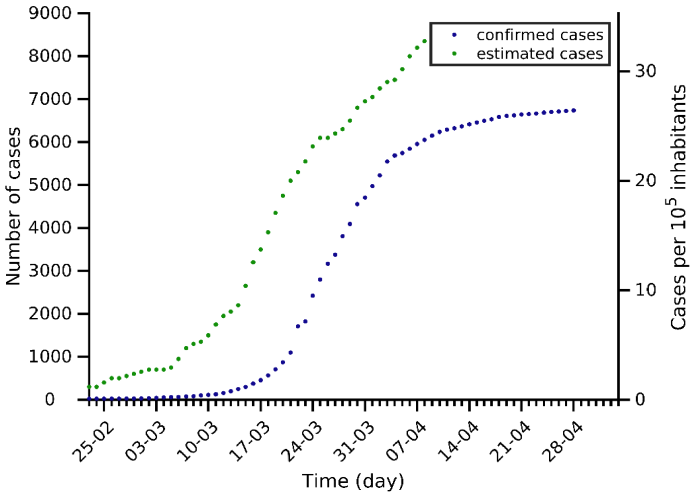


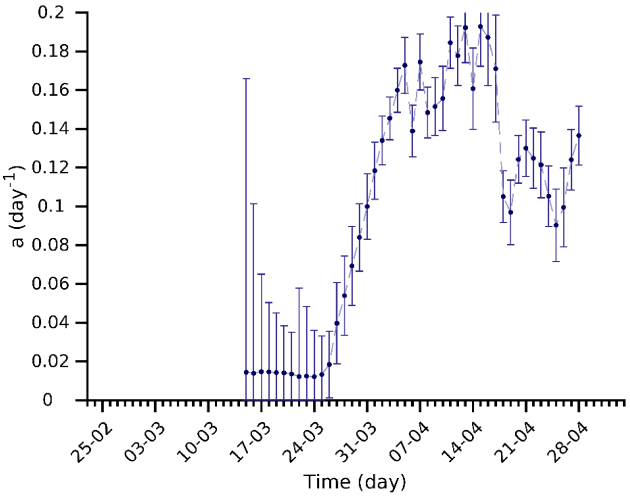


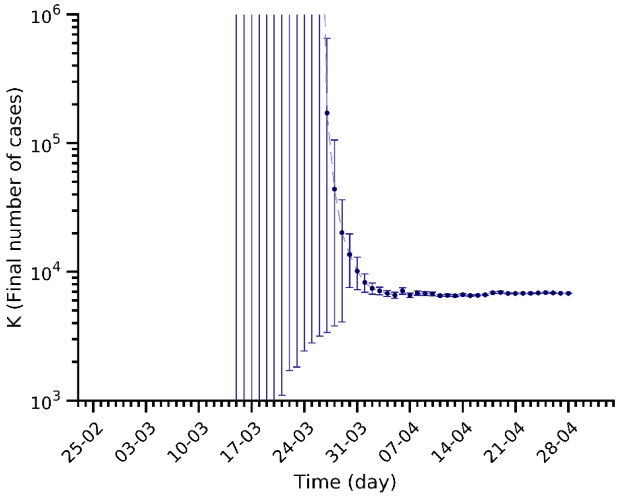


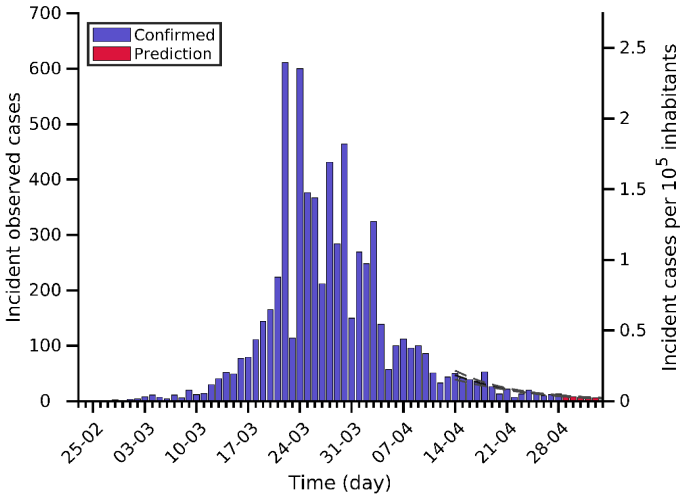
Australia 28-04-2020. Population: 25.5M. Current cumulated incidence: $26/10^5$

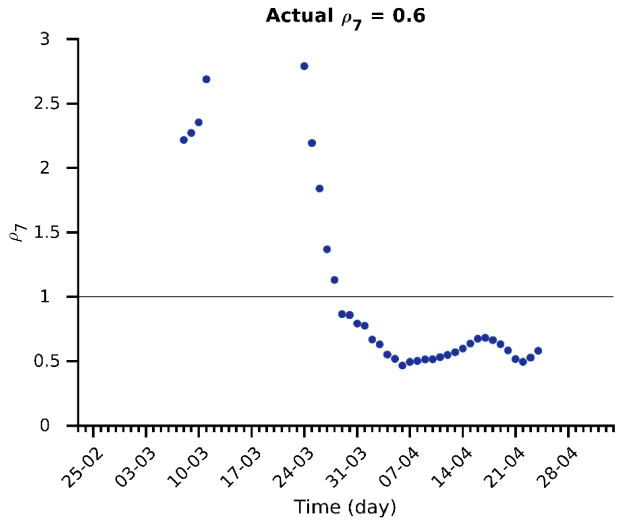


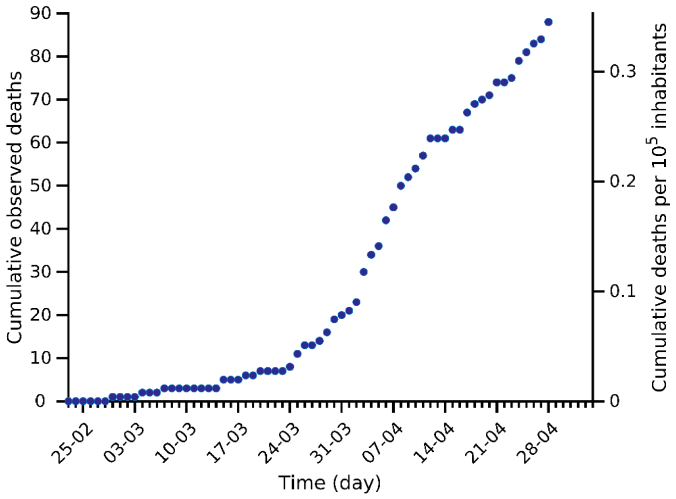


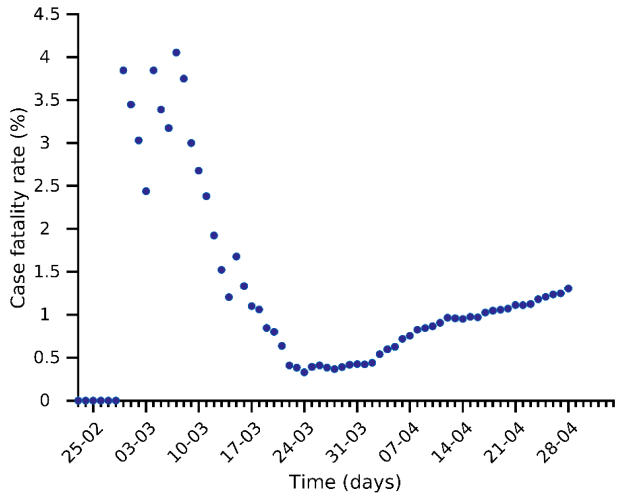




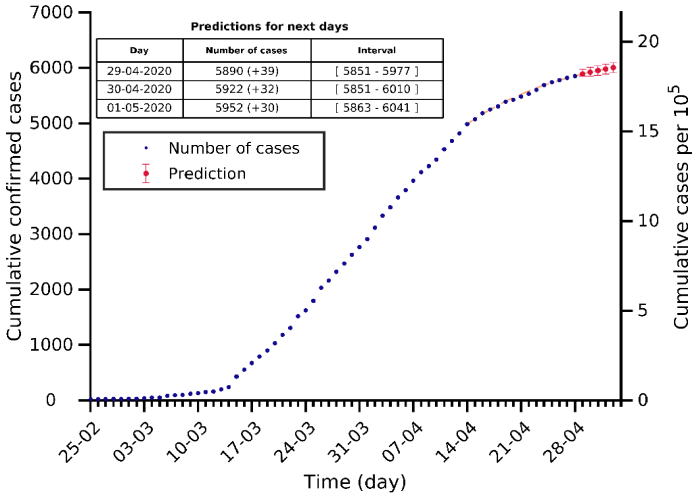


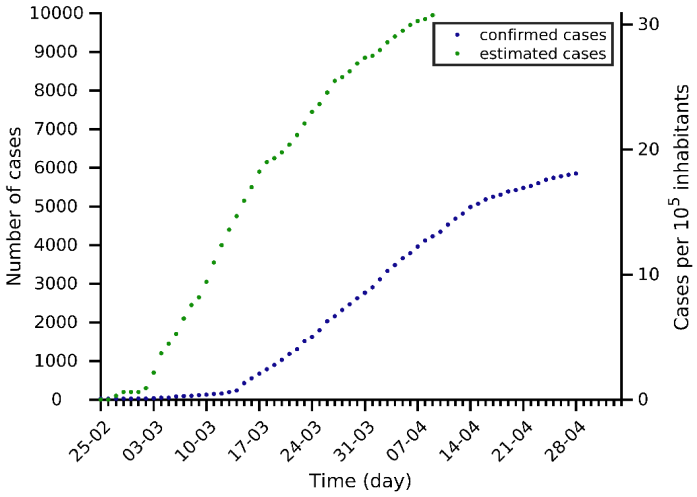


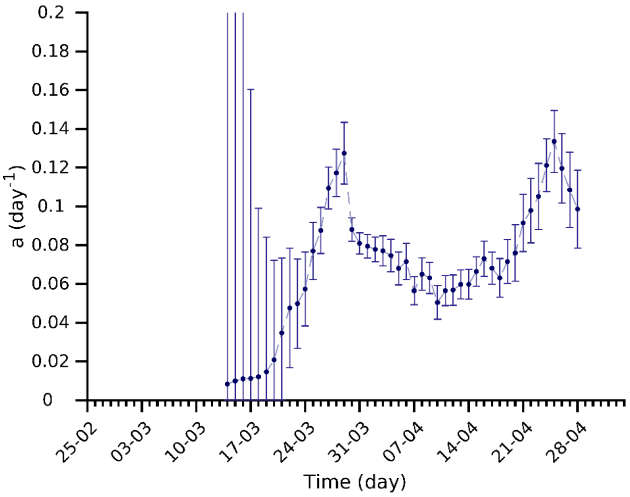


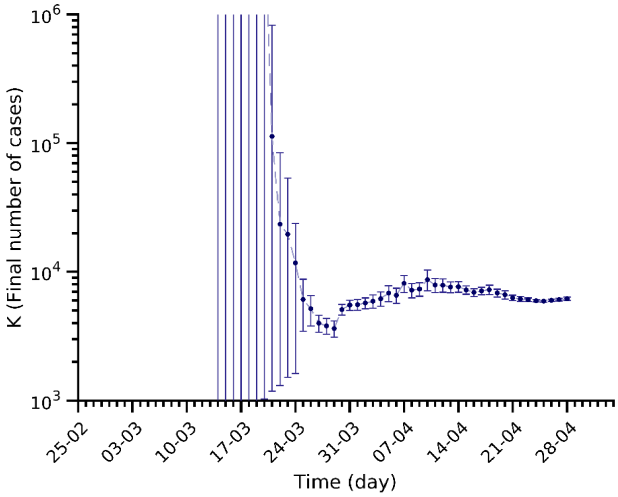


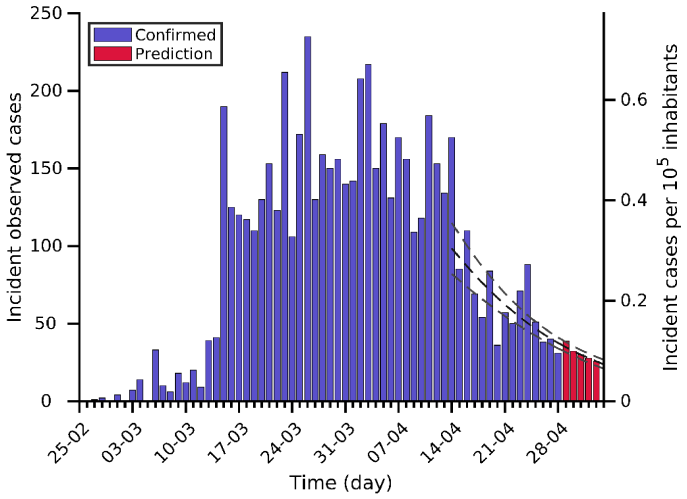
Malaysia 28-04-2020. Population: 32.4M. Current cumulated incidence: $18/10^5$

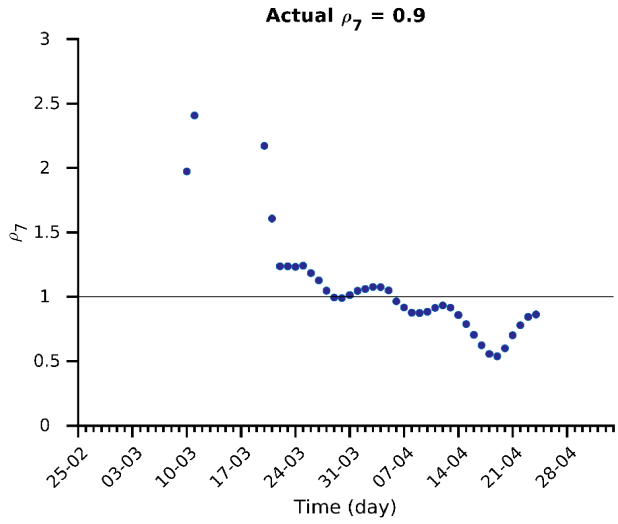


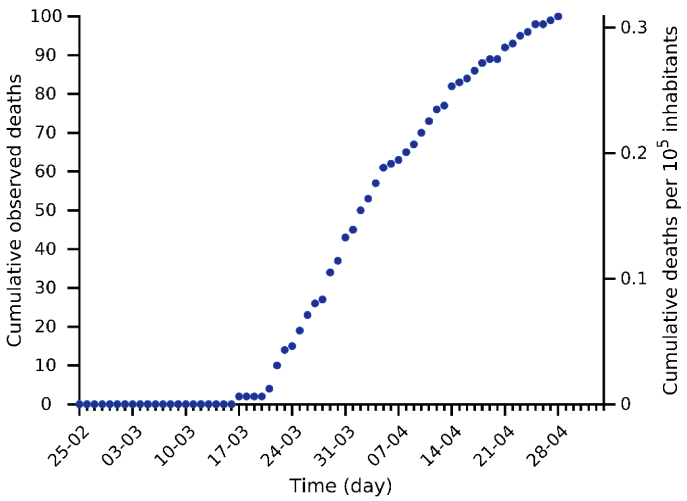


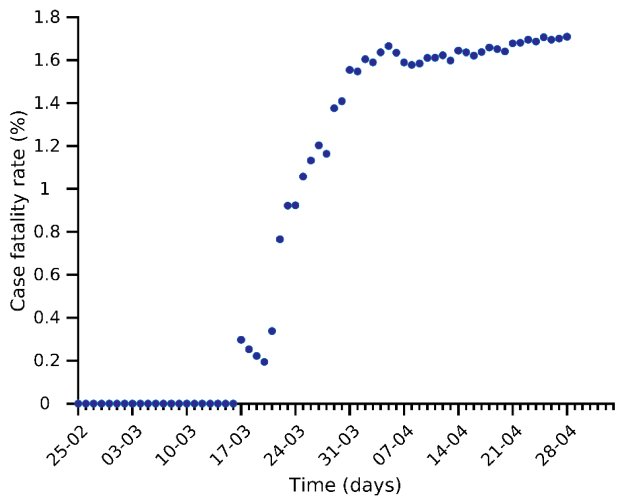




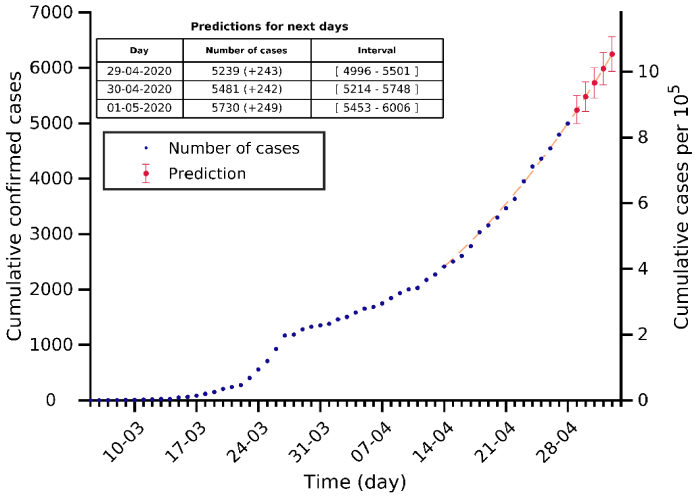


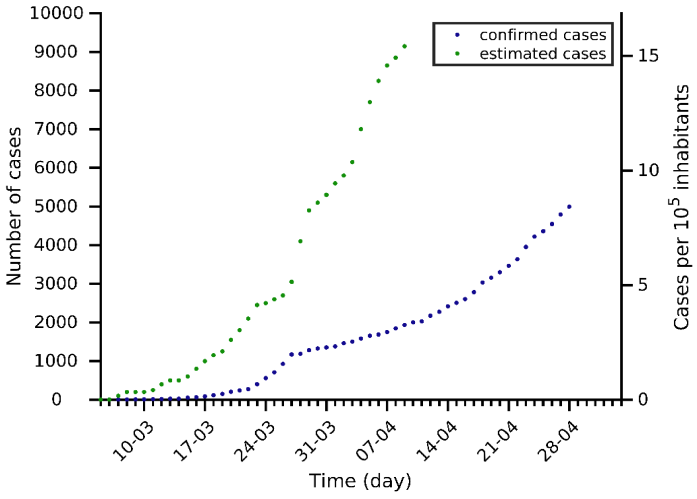


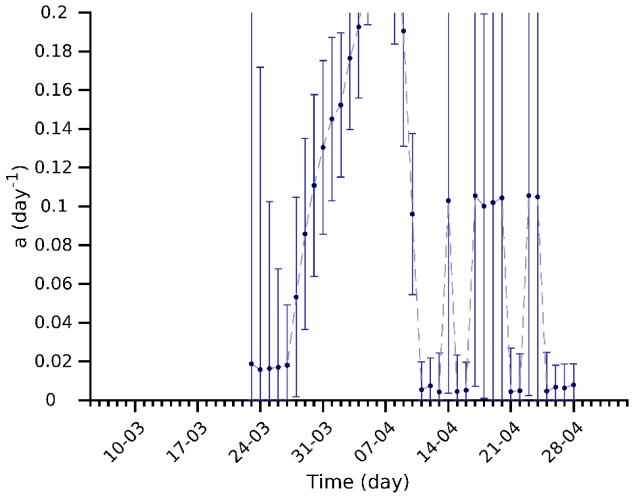


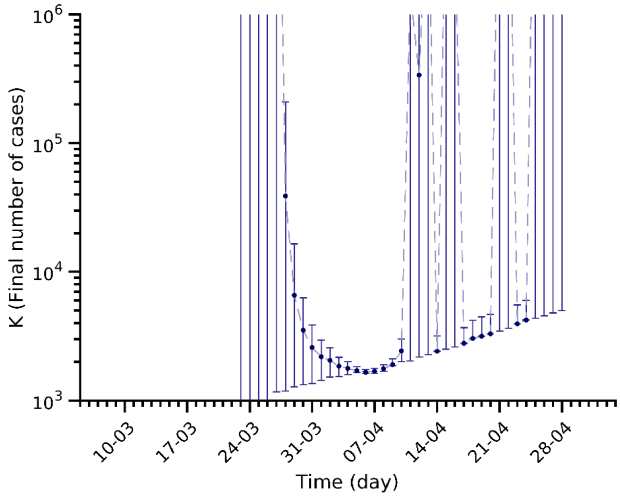


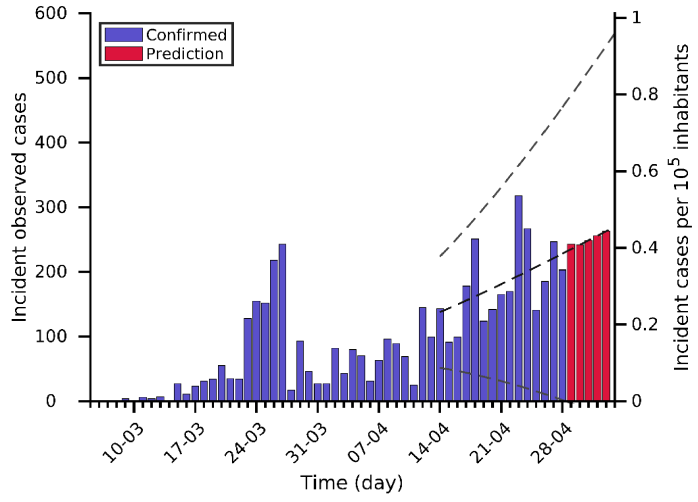
South Africa 28-04-2020. Population: 59.3M. Current cumulated incidence: 8/10^5

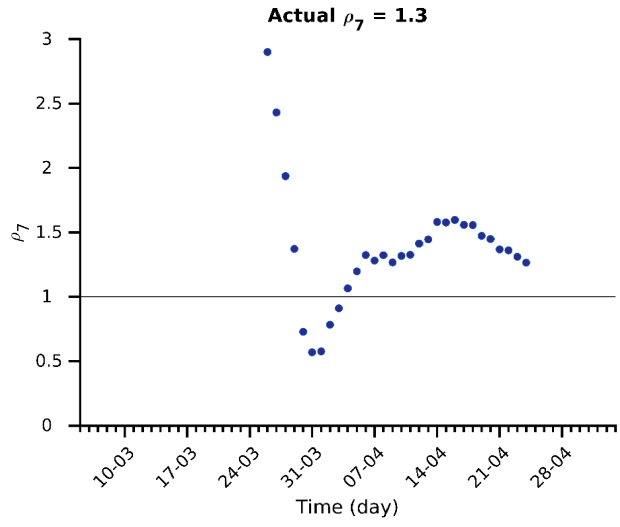


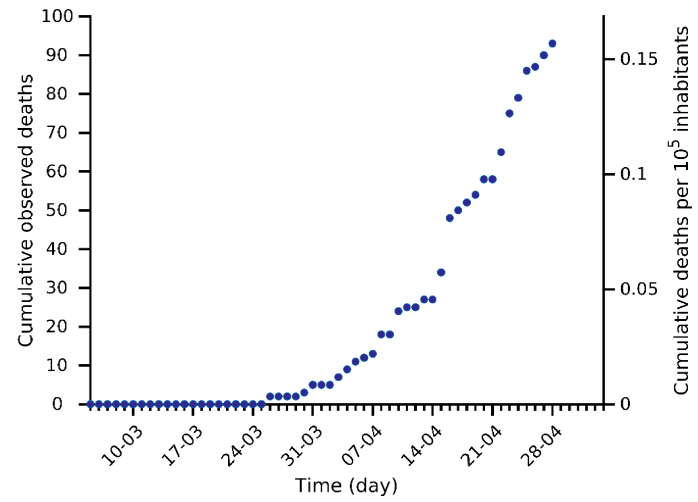


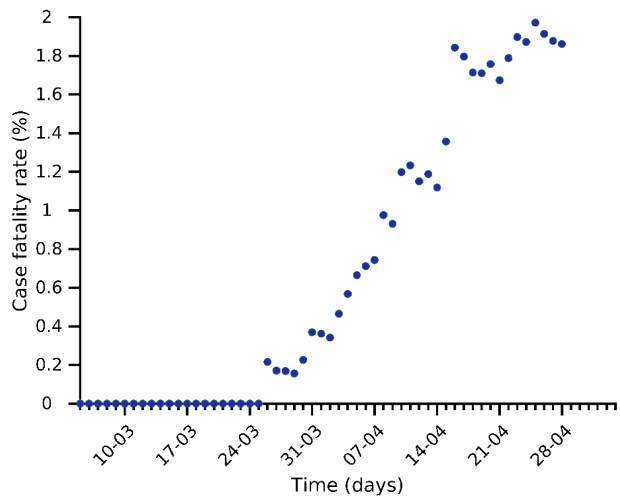








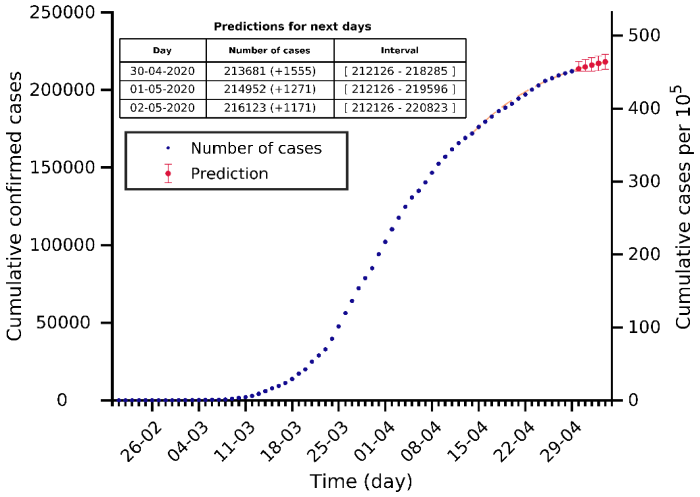


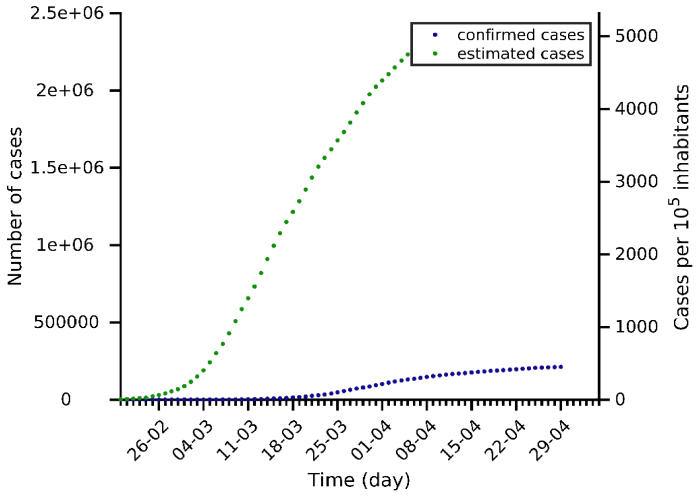


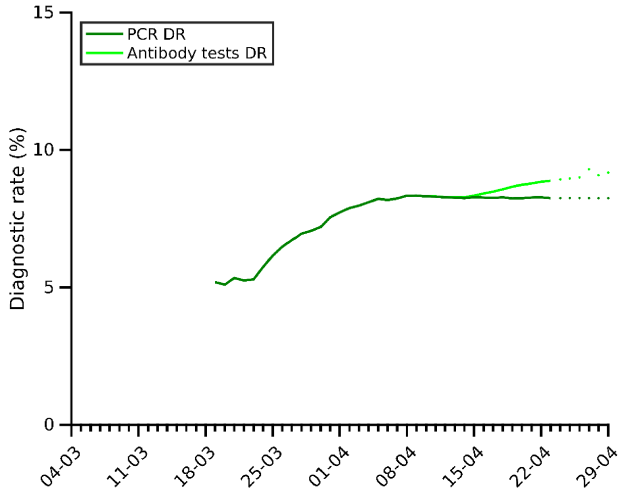
(3) Analysis and prediction of COVID-19 for Spain and its autonomous communities

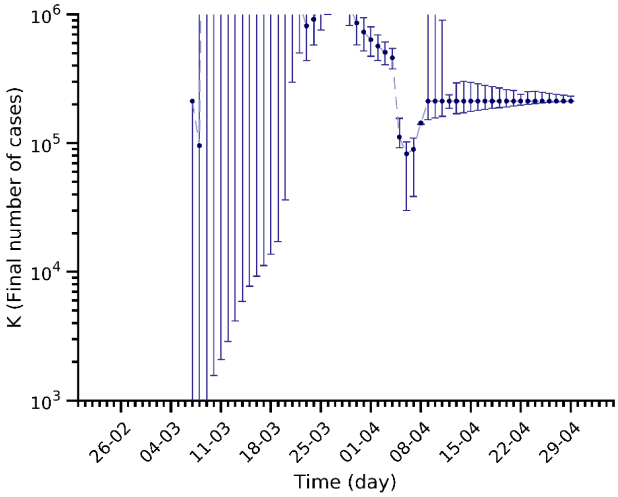
Data obtained from https://github.com/datadista/datasets/tree/master/COVID%2019 and https://covid19.isciii.es/

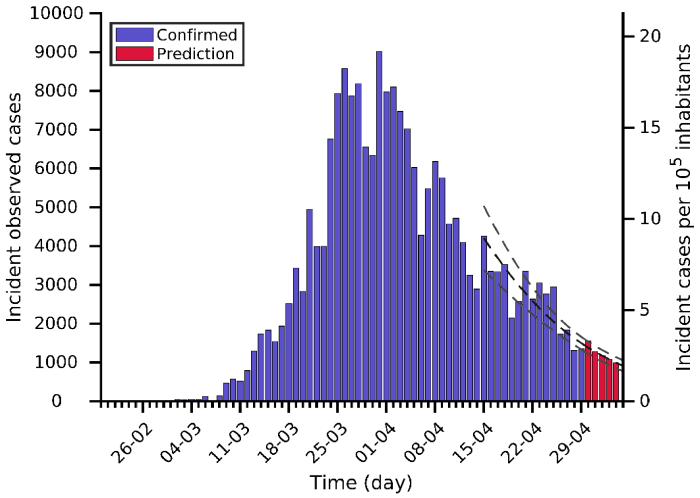
Spain 29-04-2020. Population: 47.0M. Current cumulated incidence: 451/10^5

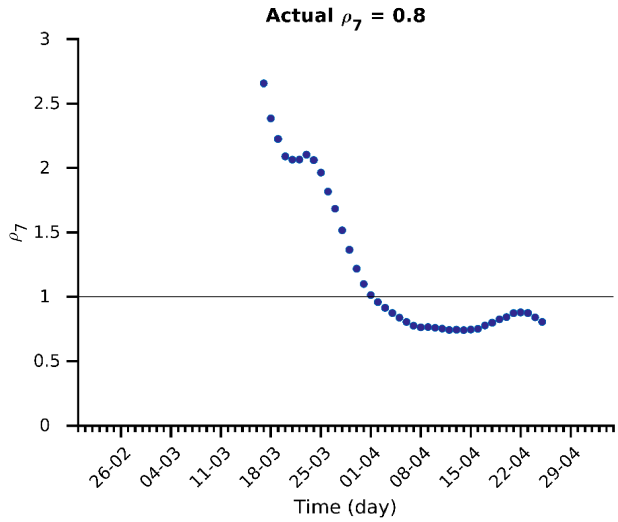


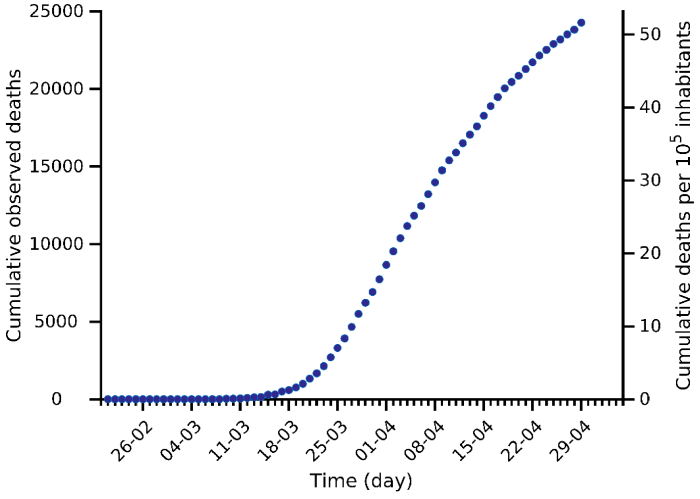


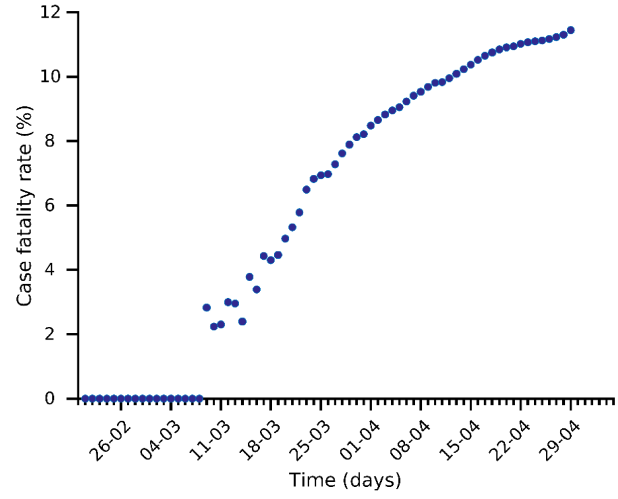




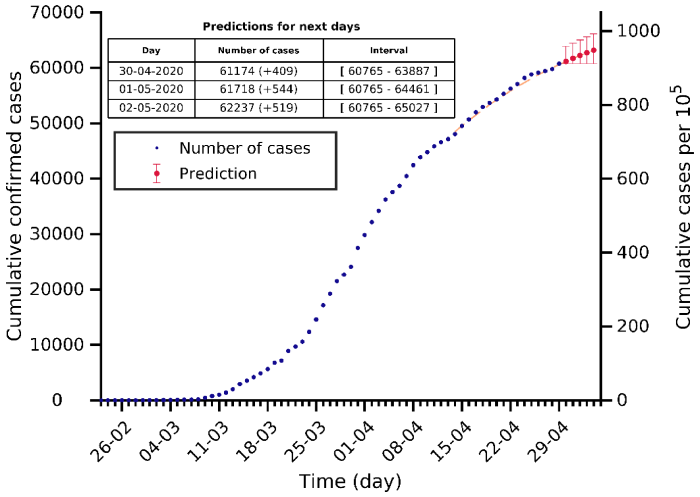


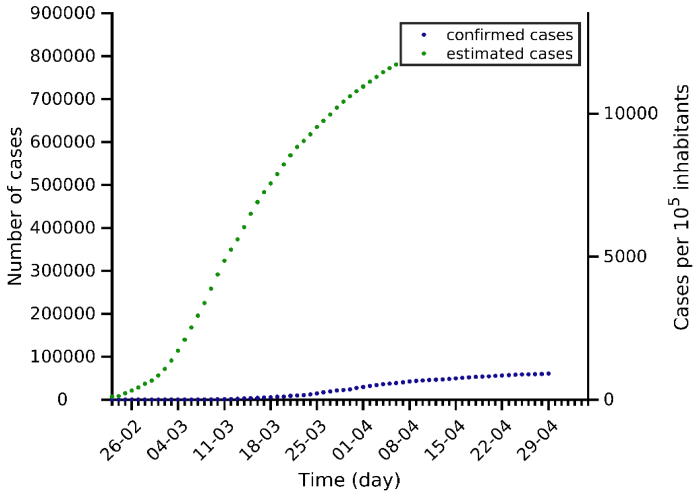


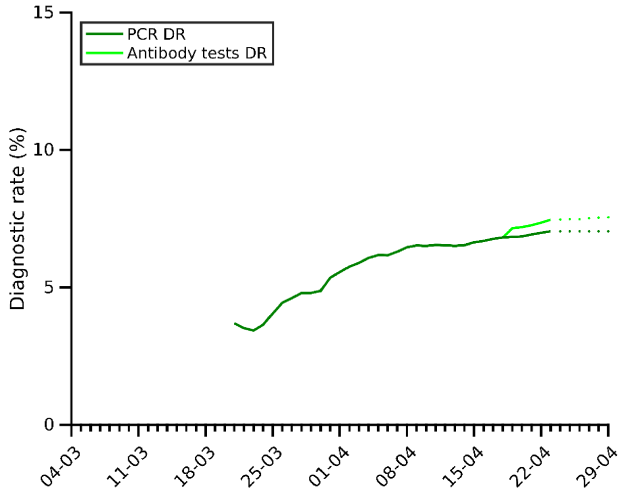


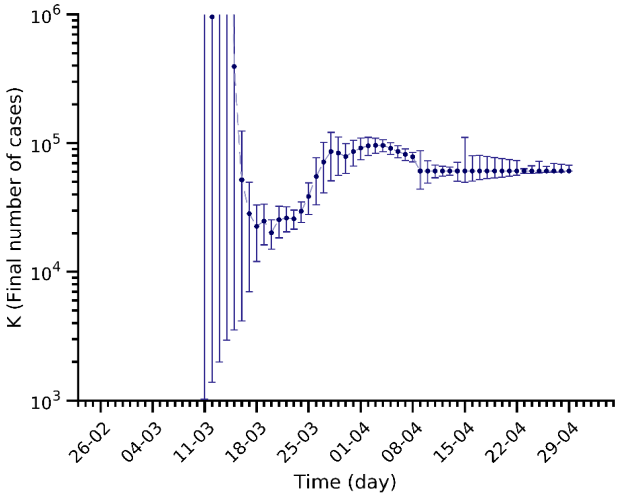


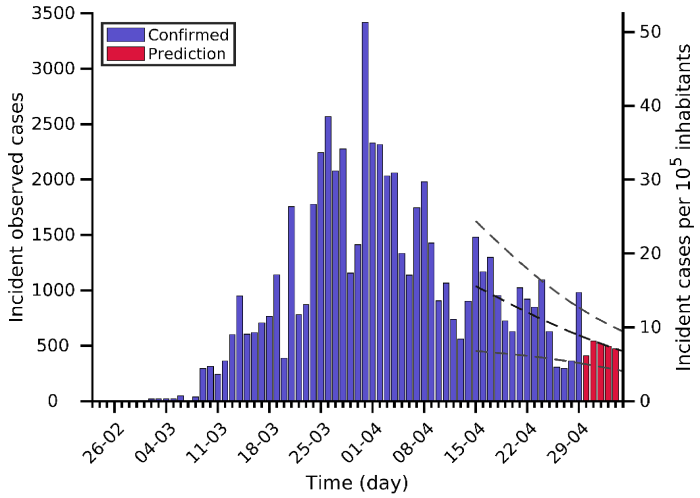
Madrid 29-04-2020. Population: 6.7M. Current cumulated incidence: 912/10^5

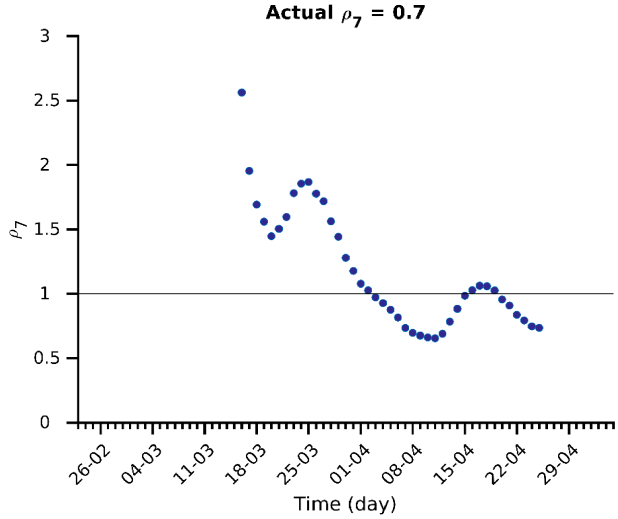


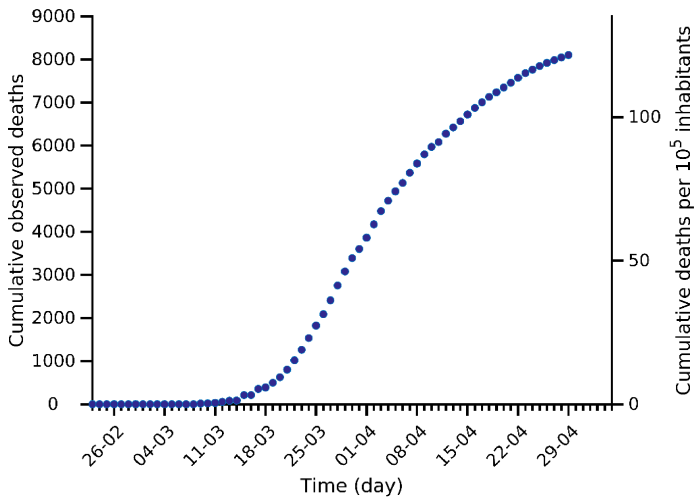


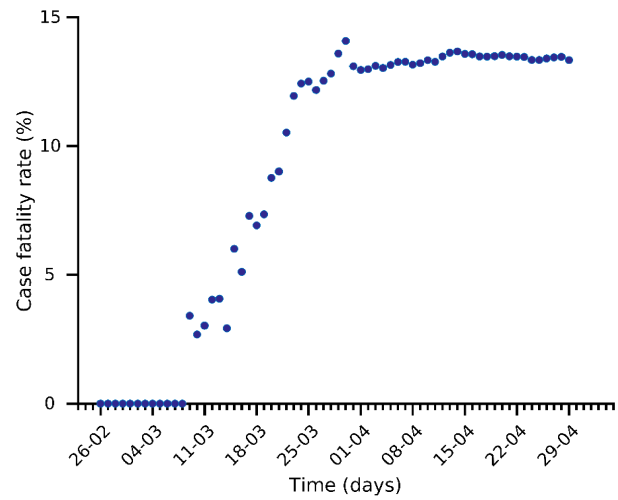




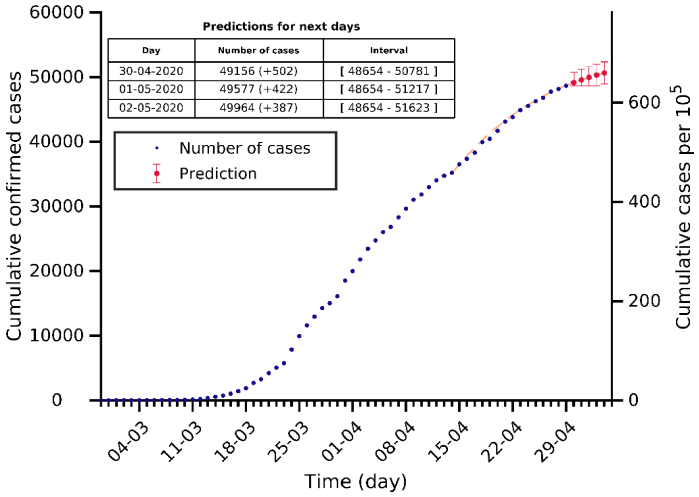


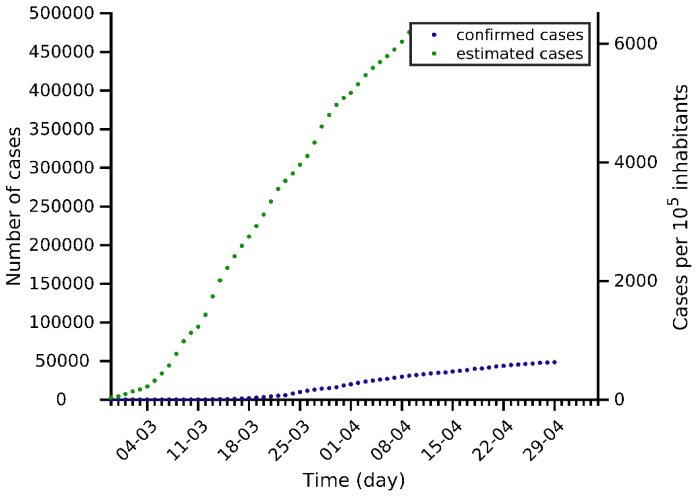


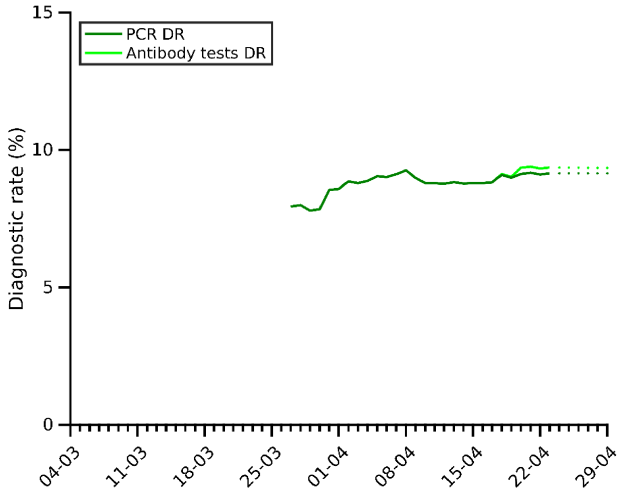


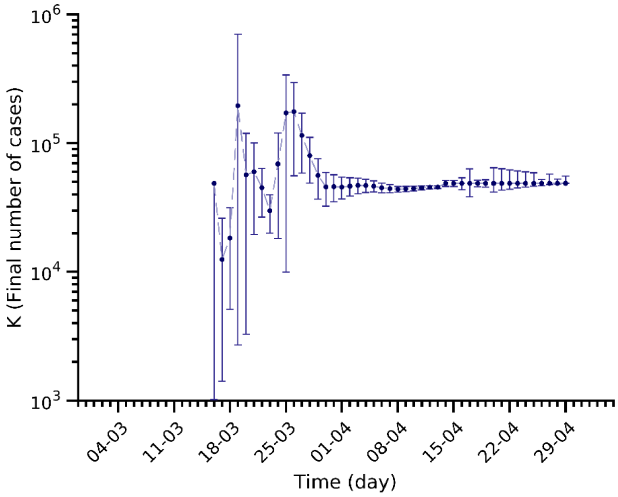


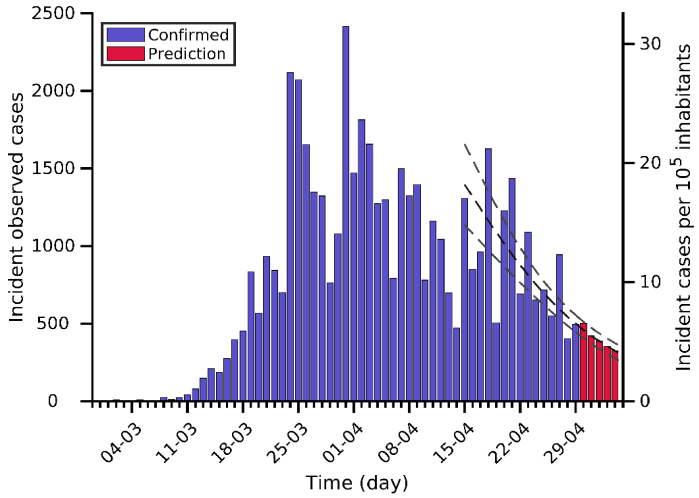
Catalunya 29-04-2020. Population: 7.7M. Current cumulated incidence: $634/10^5$

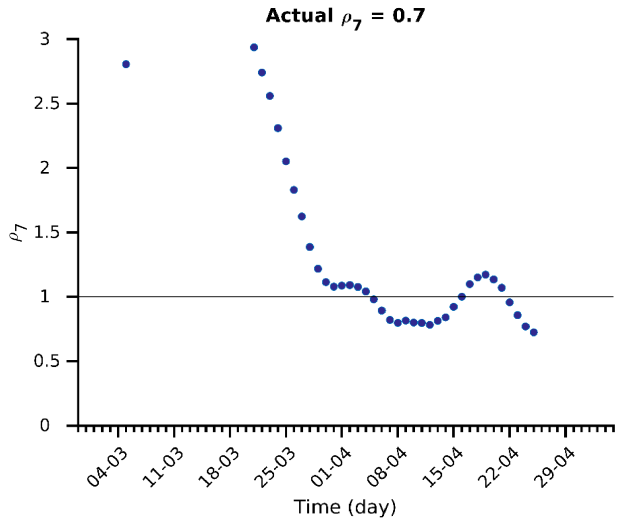


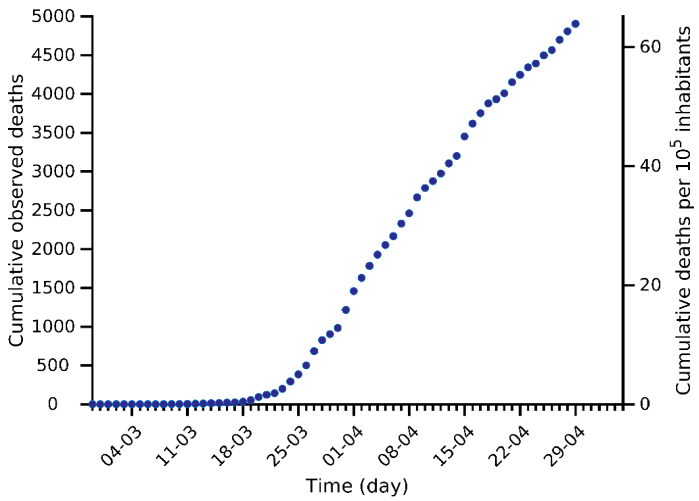


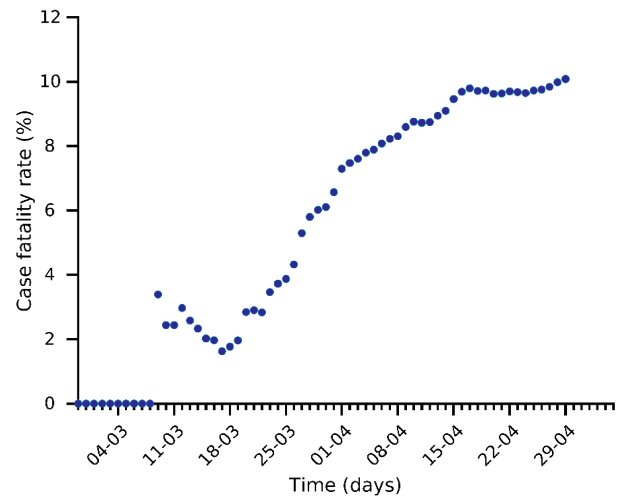




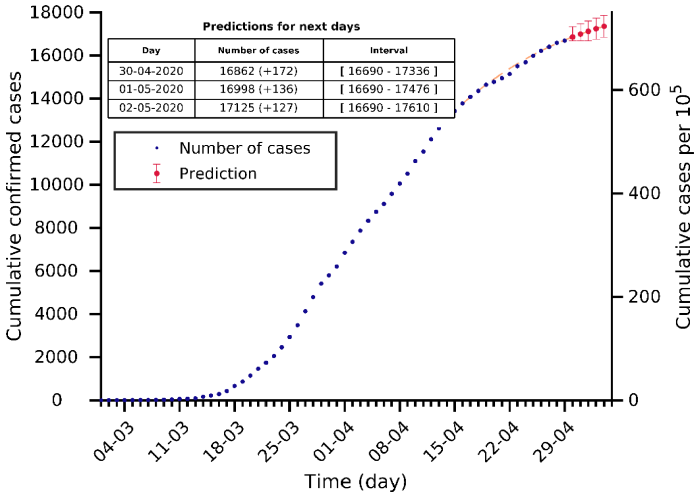


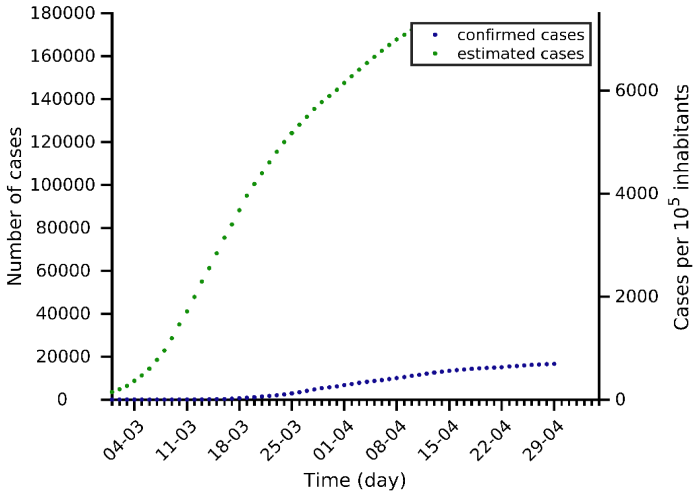


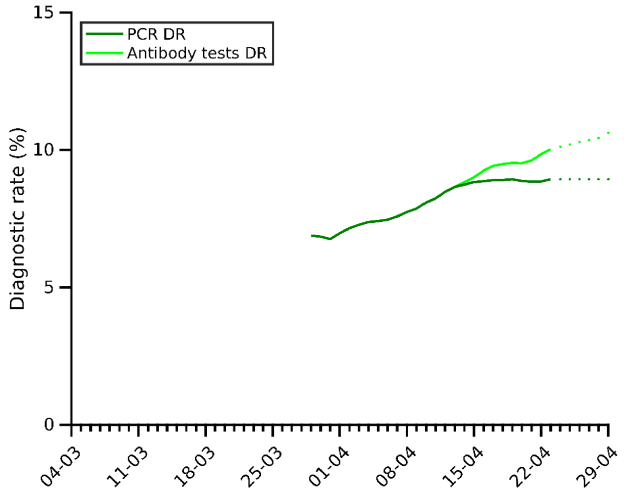


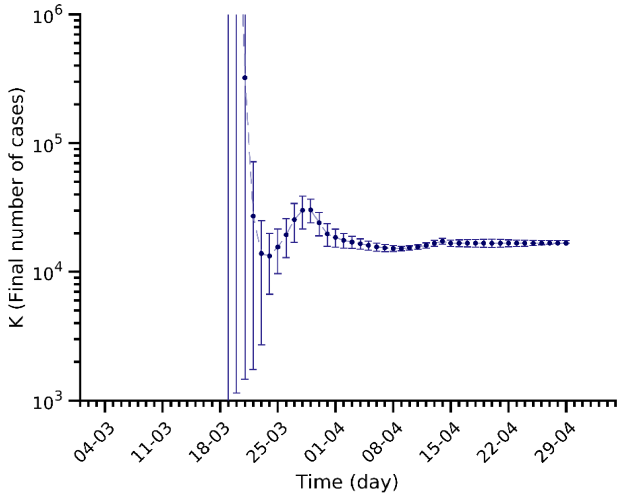


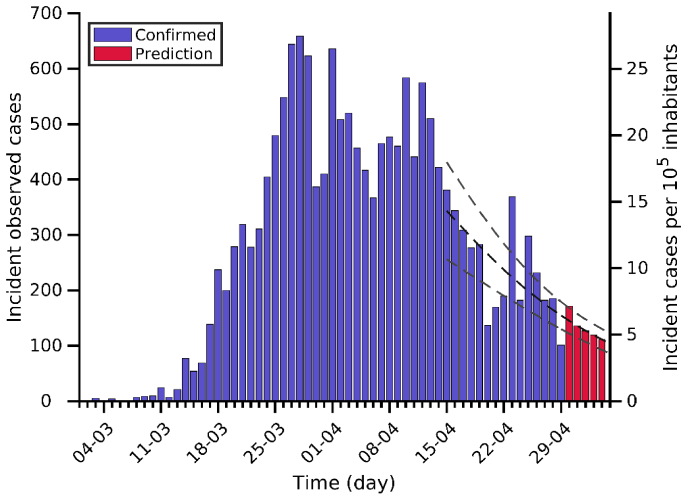
Castilla Leon 29-04-2020. Population: 2.4M. Current cumulated incidence: 696/10^5

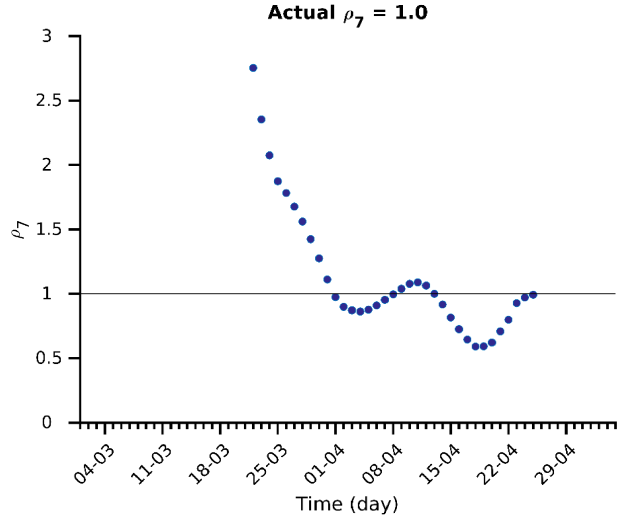


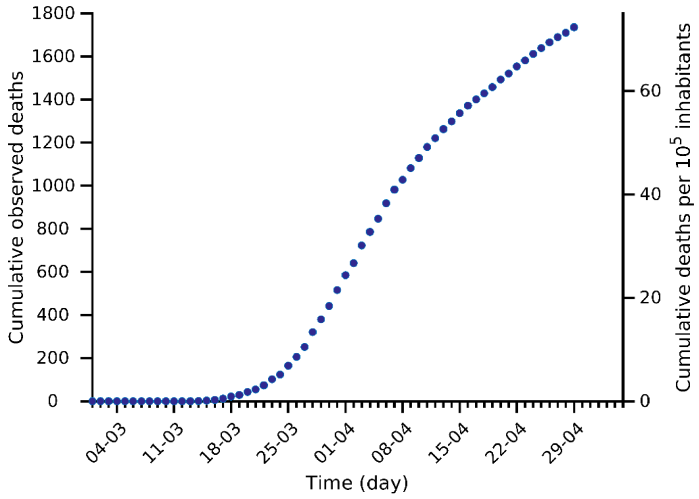


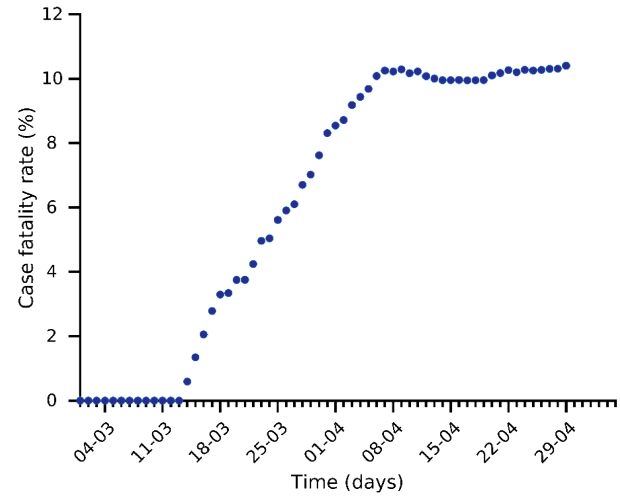




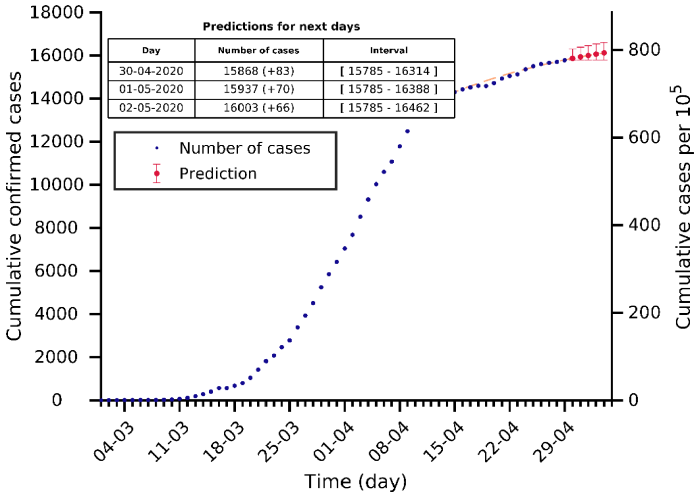


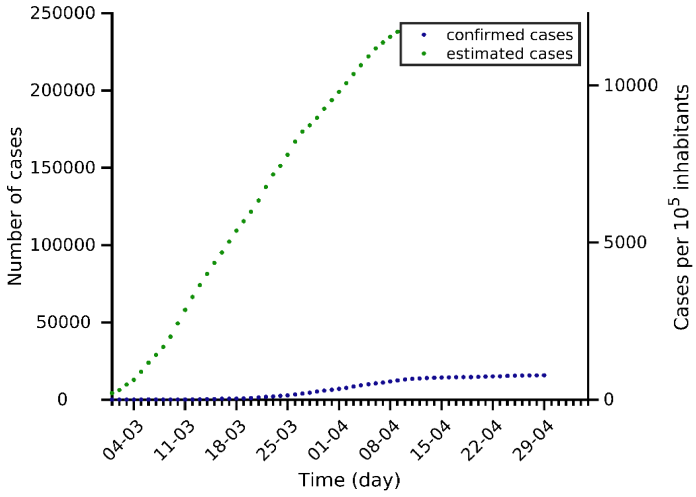


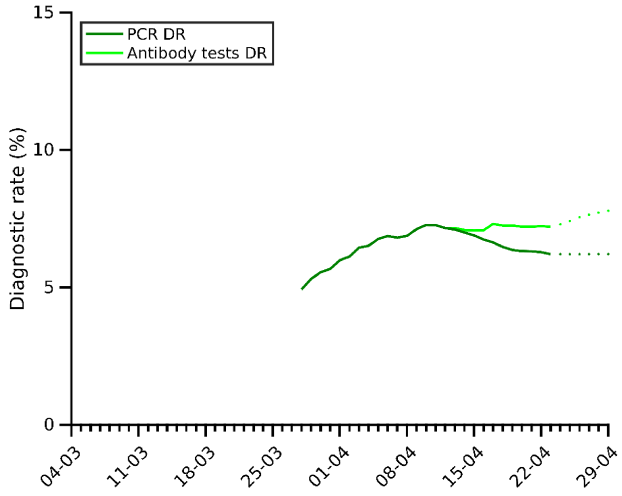


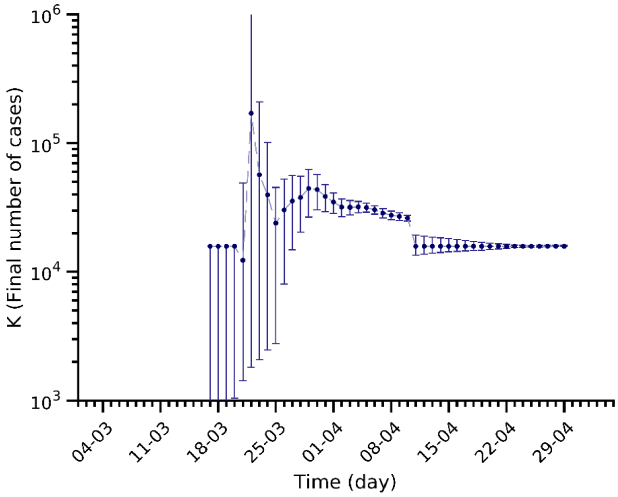


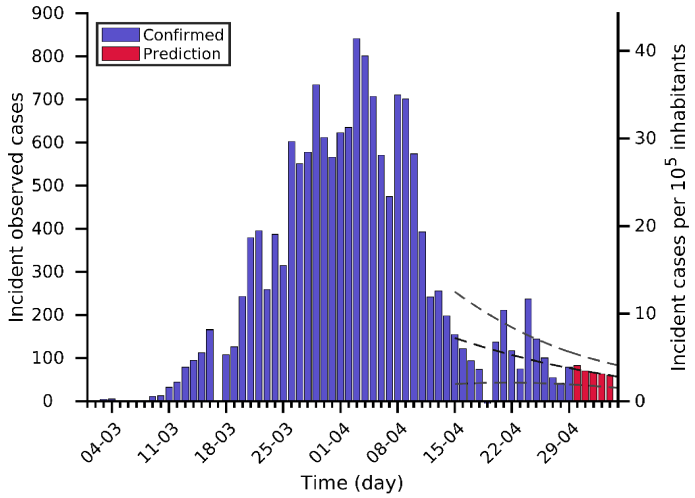
Castilla-La Mancha 29-04-2020. Population: 2.0M. Current cumulated incidence: 77

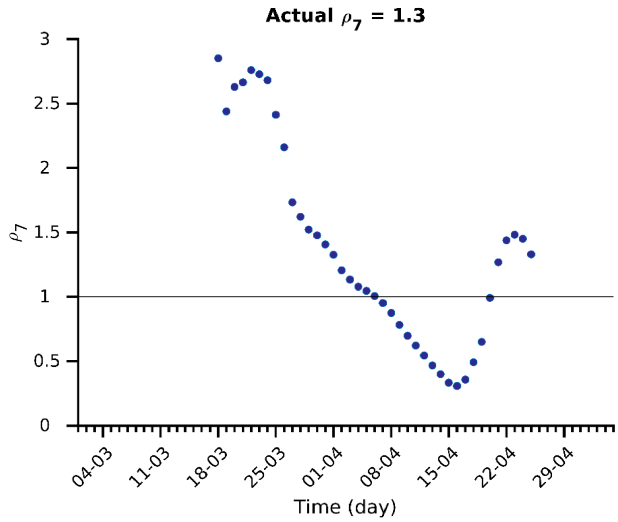


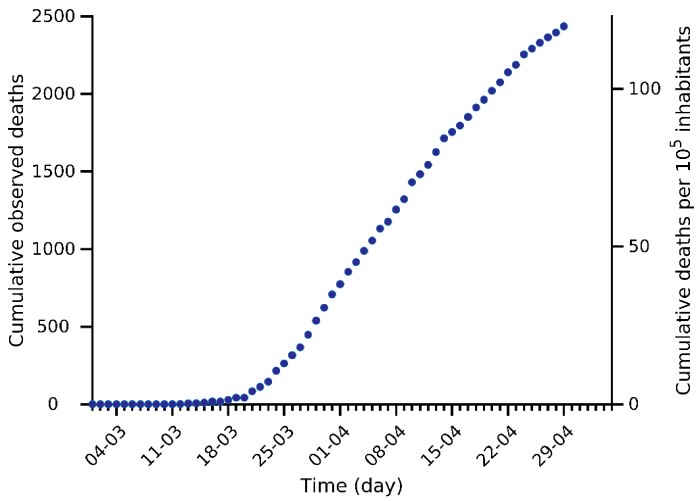


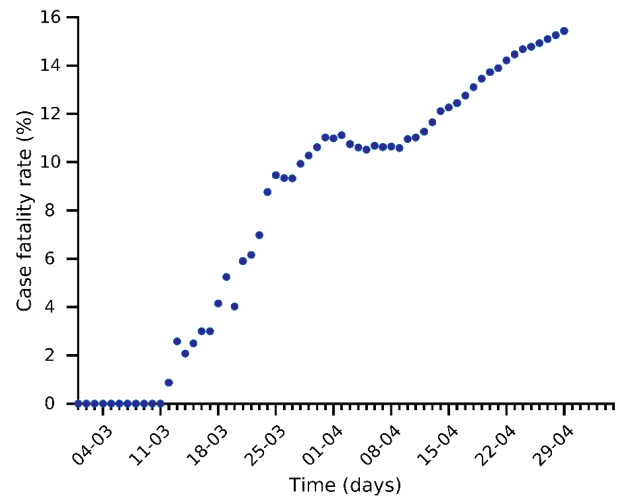




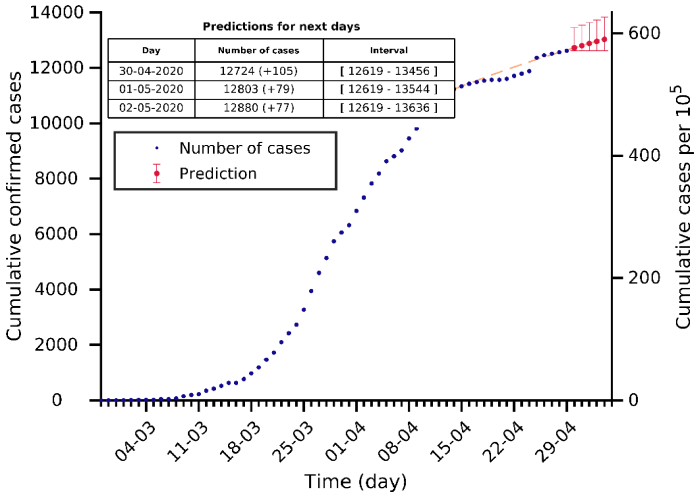


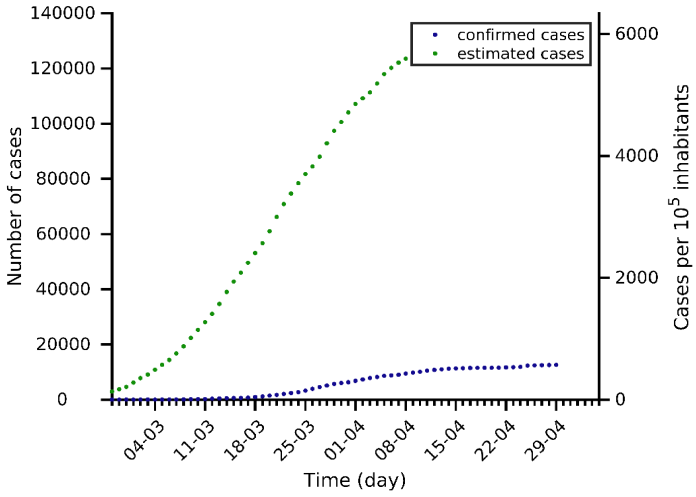


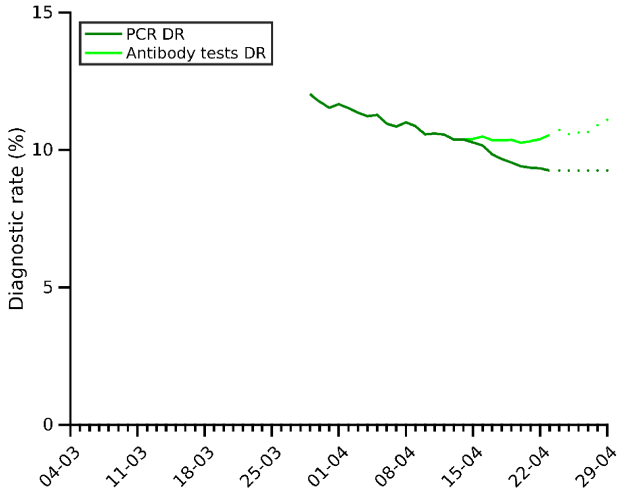


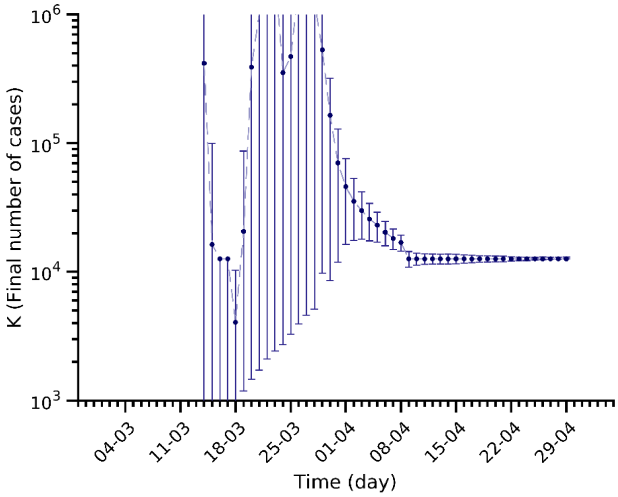


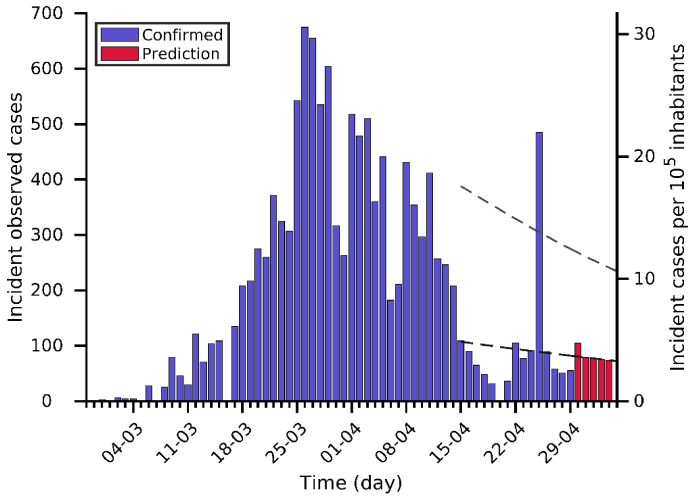
Euskadi 29-04-2020. Population: 2.2M. Current cumulated incidence: 572/10^5

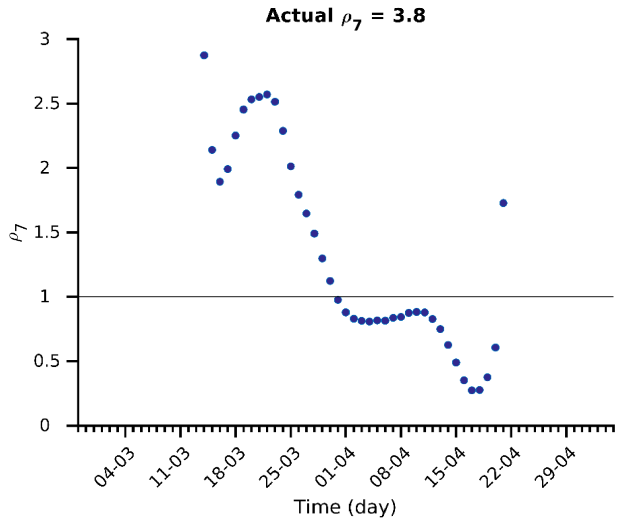


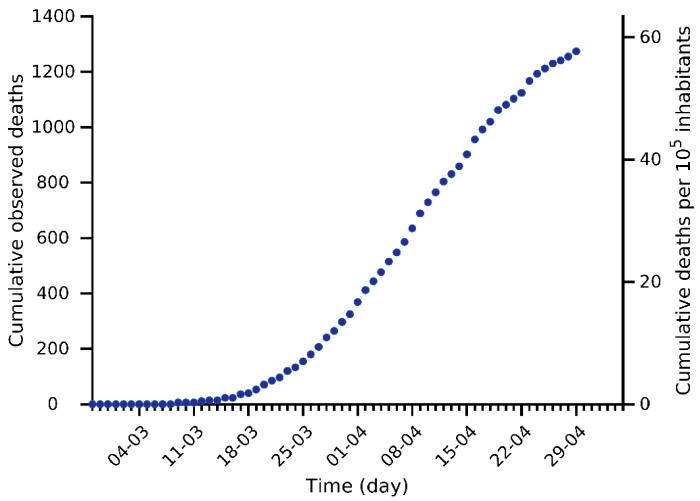


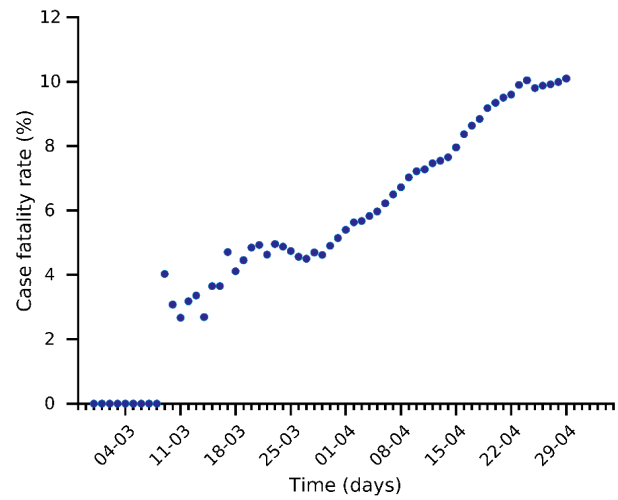




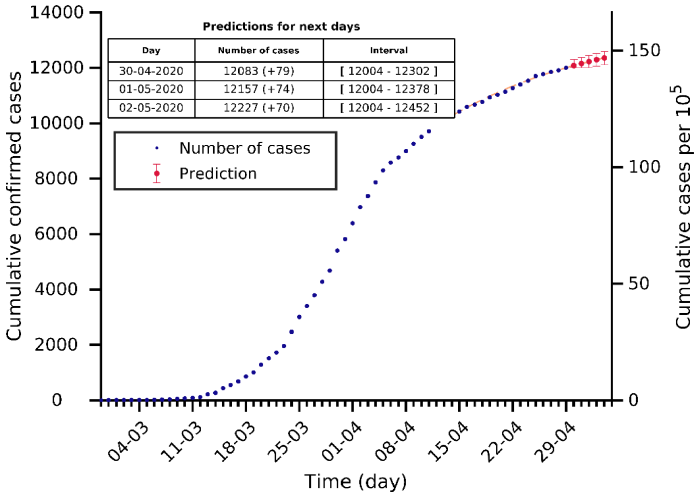


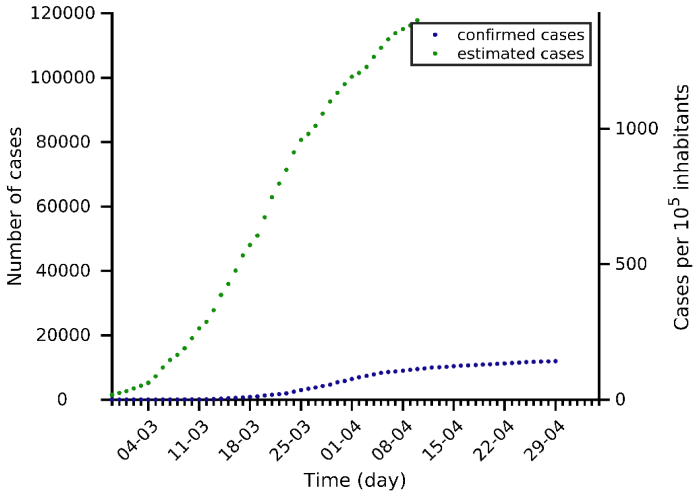


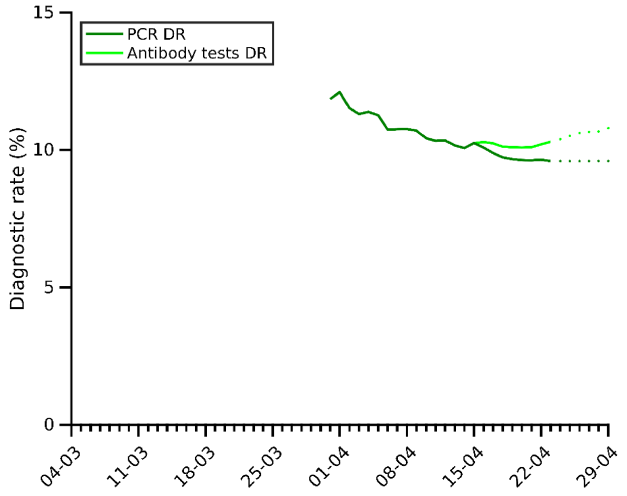


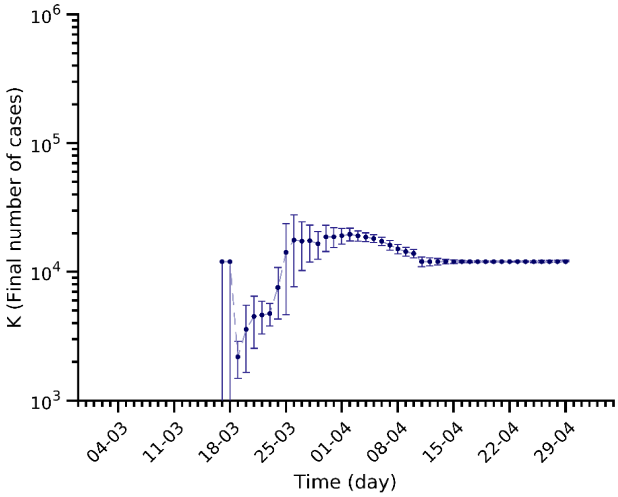


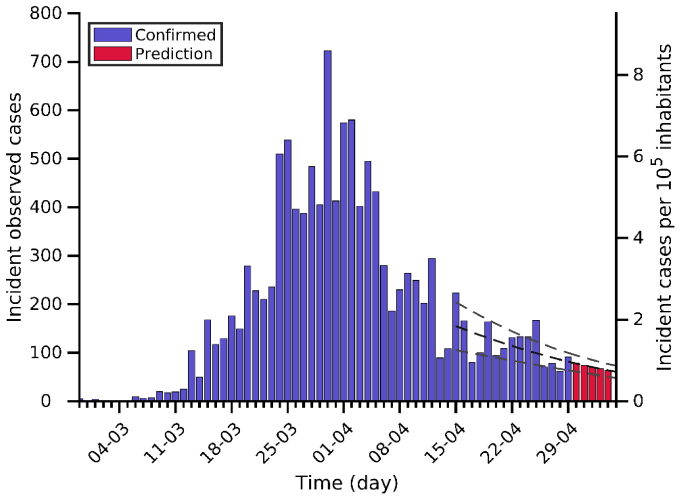
Andalucia 29-04-2020. Population: 8.4M. Current cumulated incidence: 143/10^5

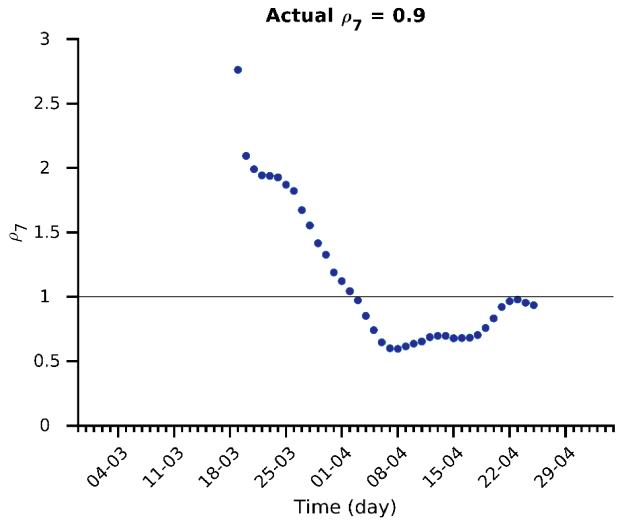


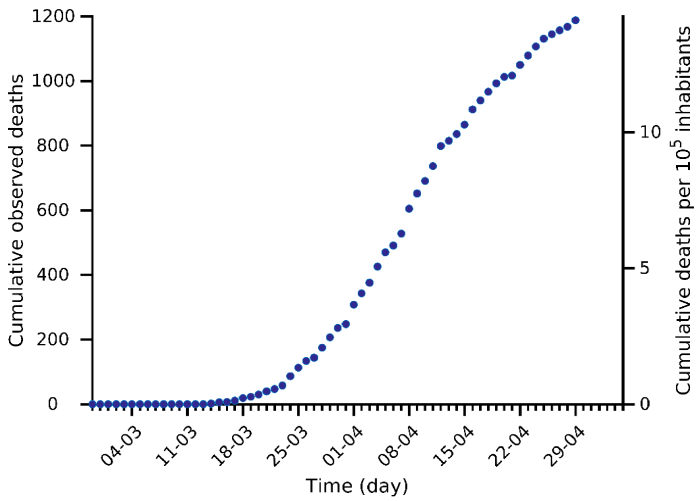


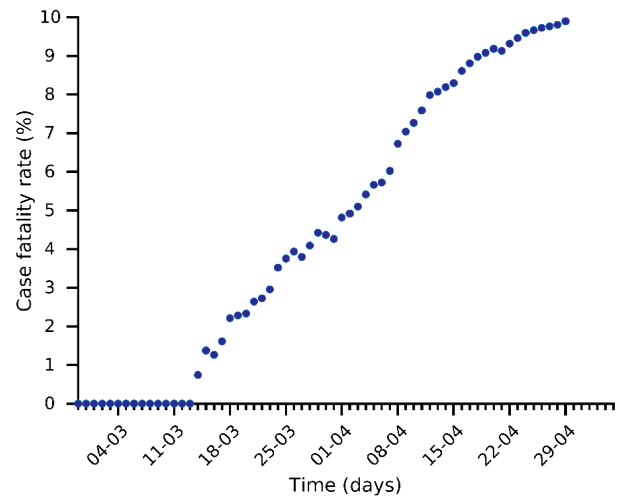




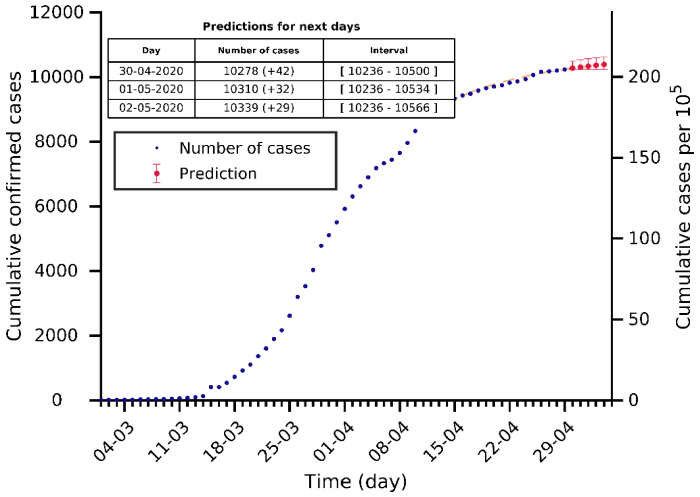


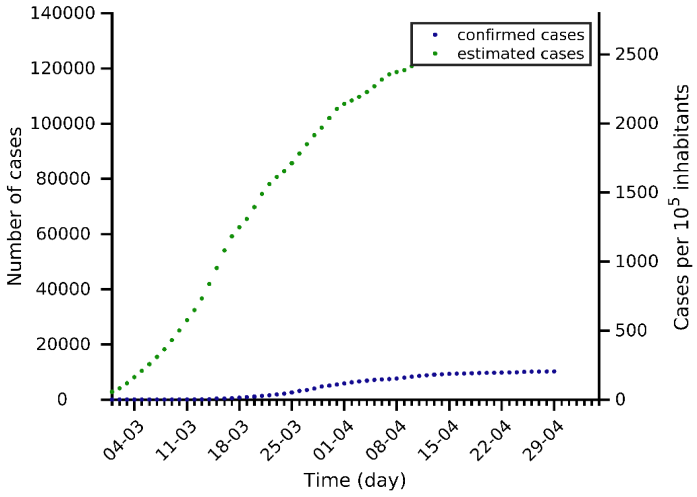


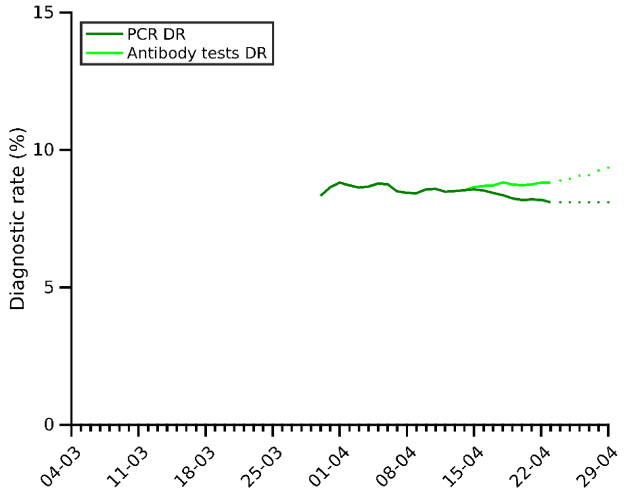


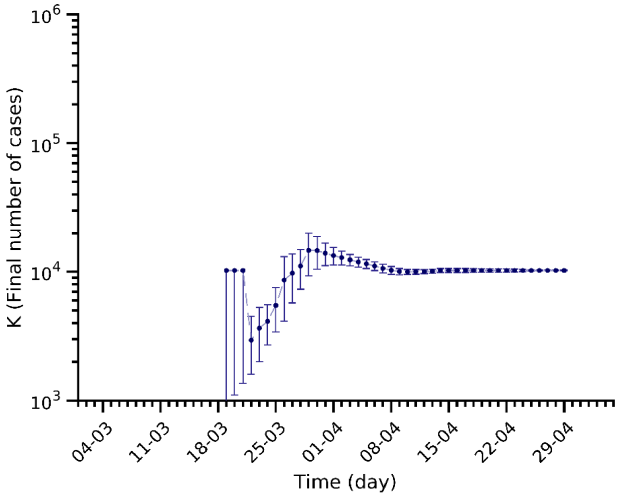


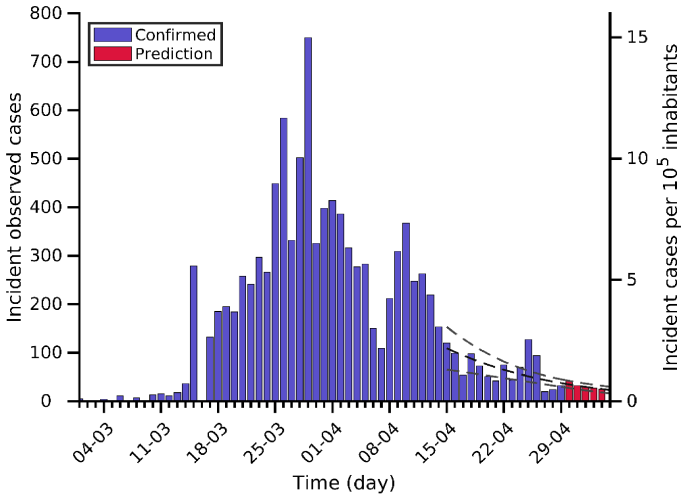
C Valenciana 29-04-2020. Population: 5.0M. Current cumulated incidence: 205/10^5

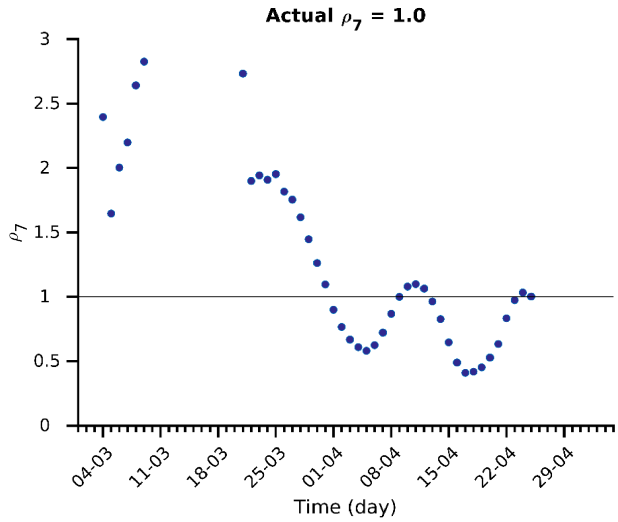


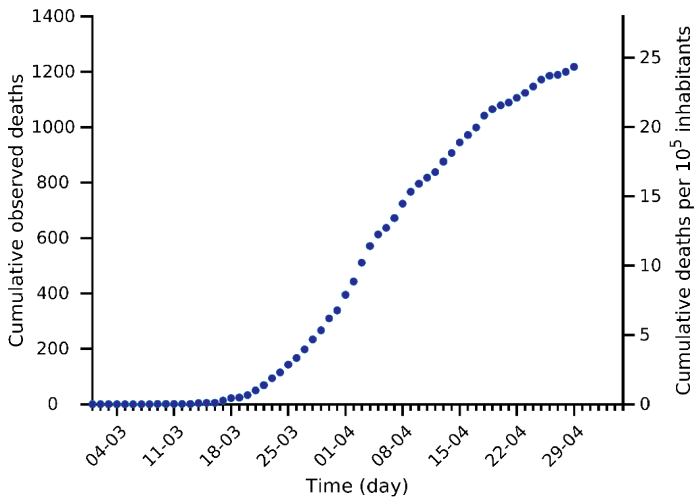


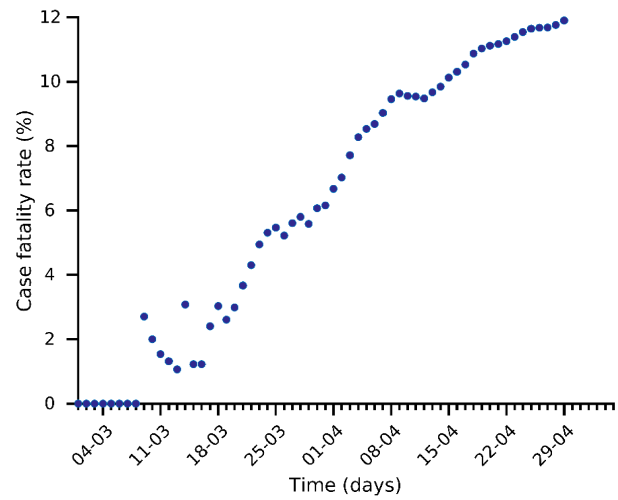




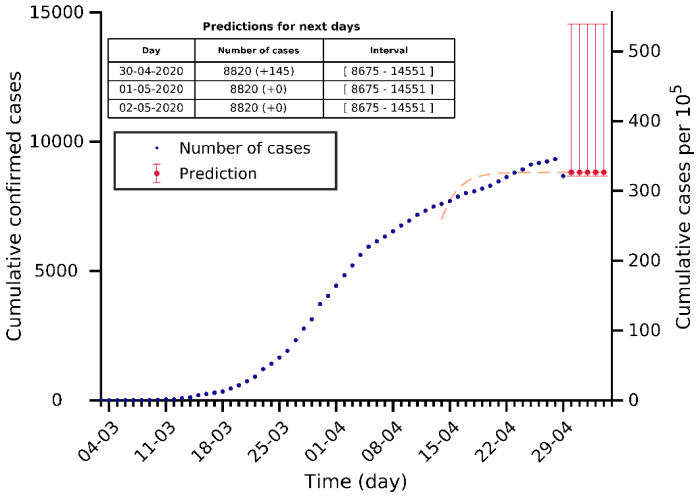


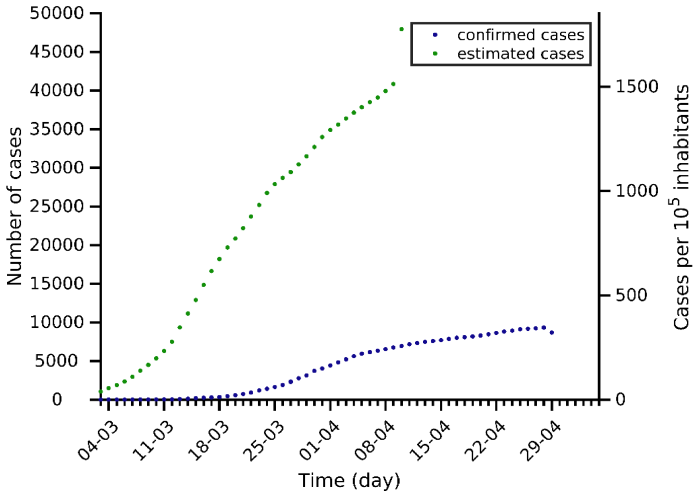


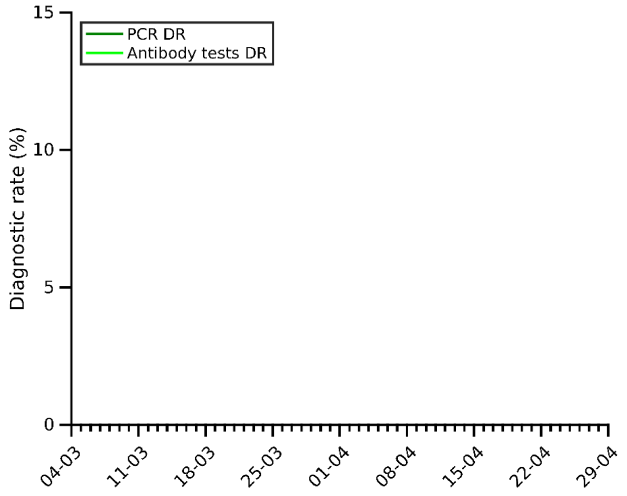


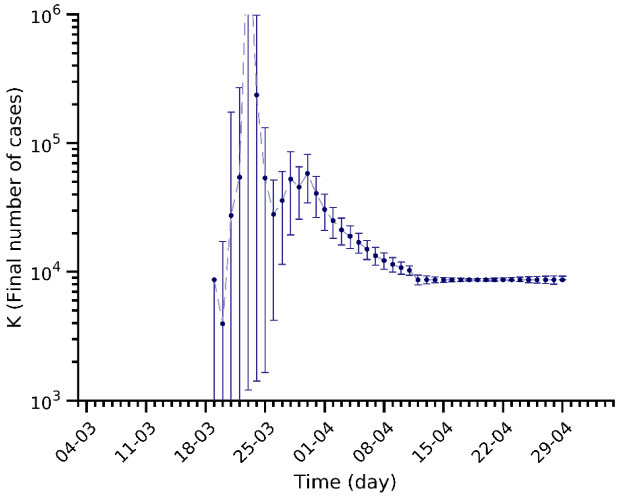


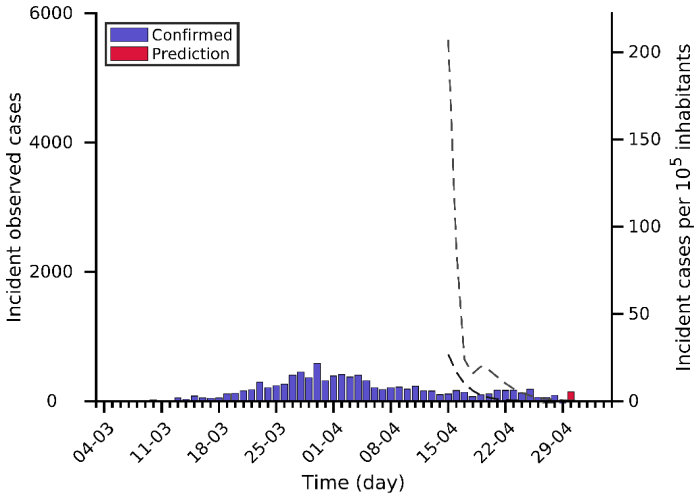
Galicia 29-04-2020. Population: 2.7M. Current cumulated incidence: 321/10⁵

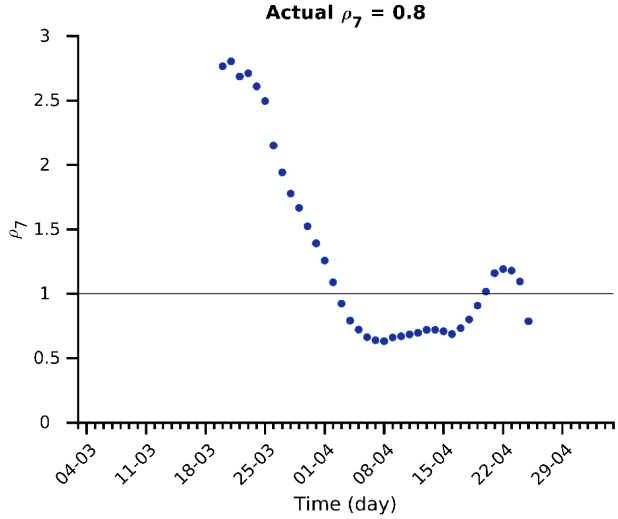


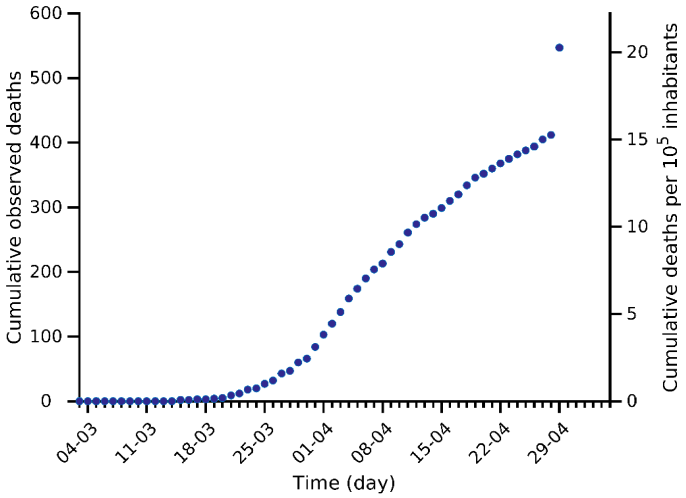


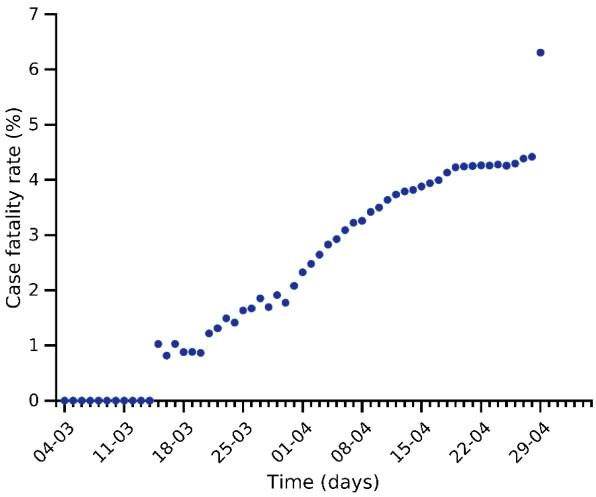




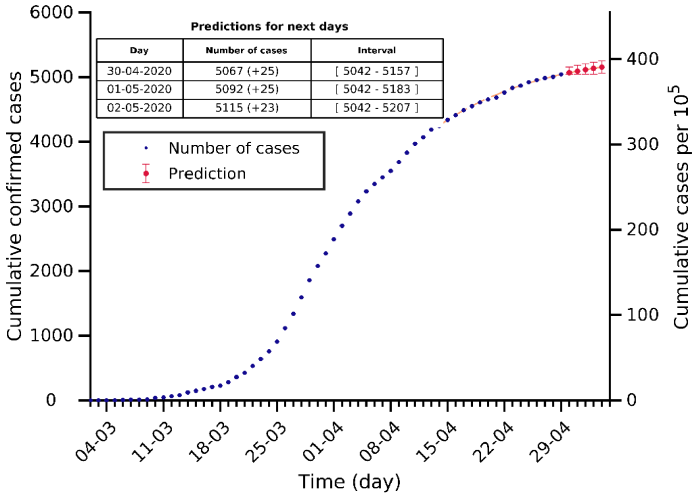


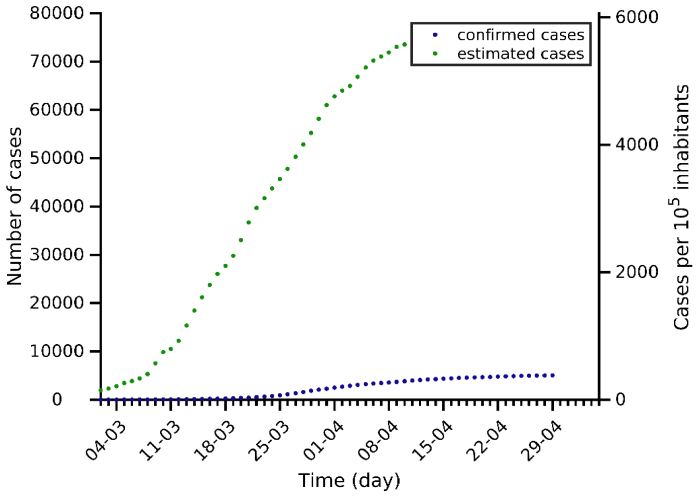


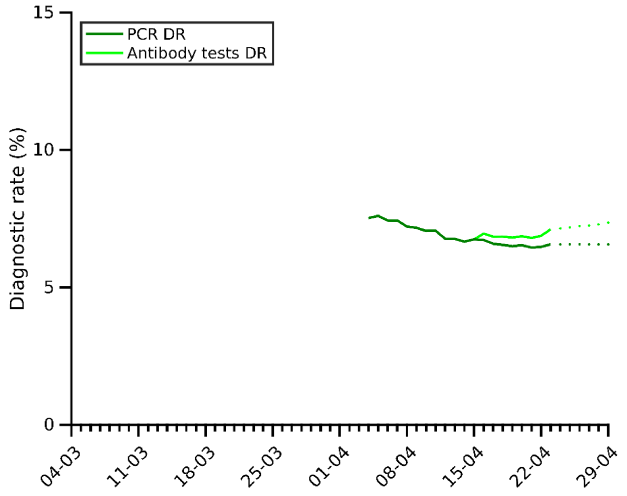


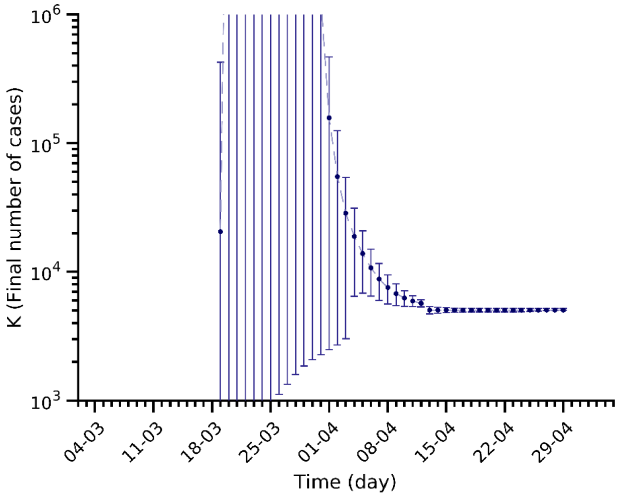


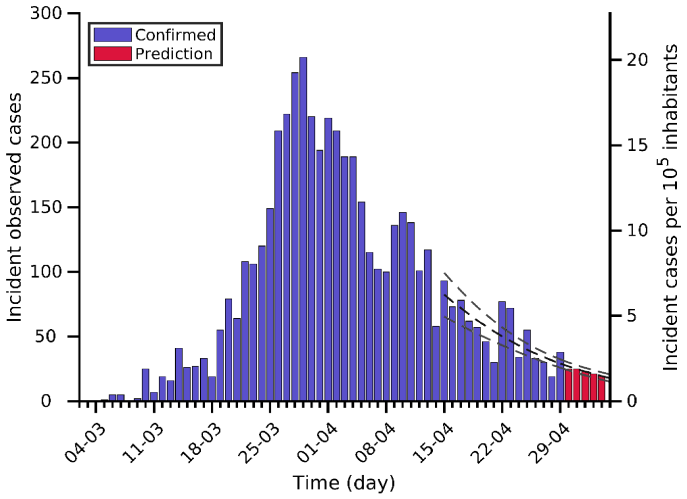
Aragon 29-04-2020. Population: 1.3M. Current cumulated incidence: 382/10⁵

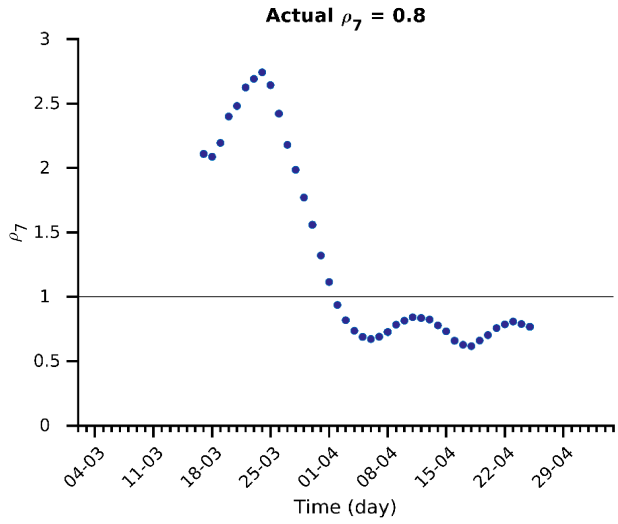


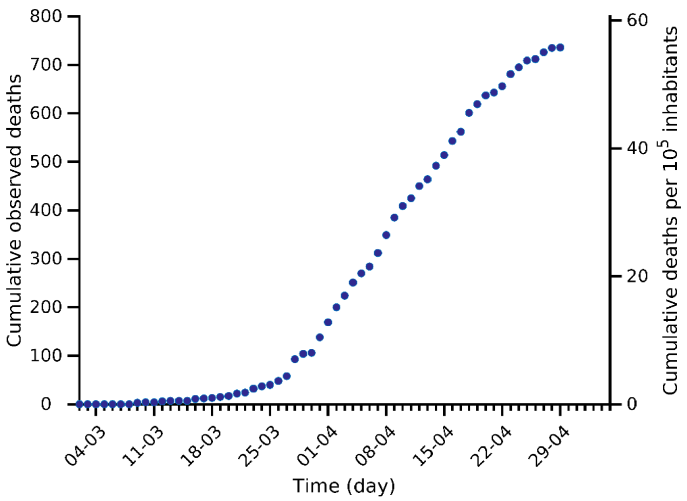


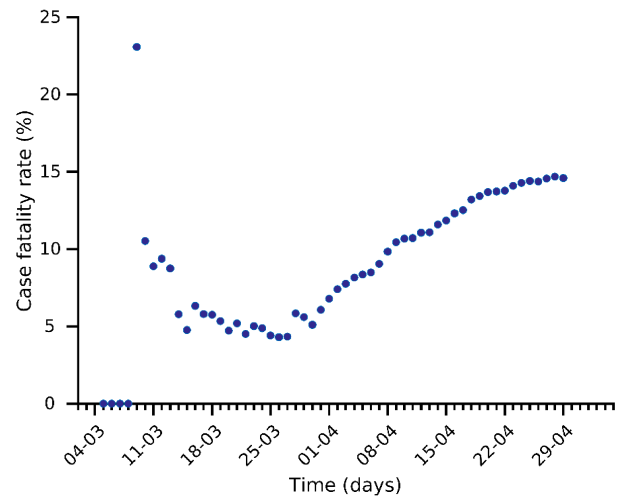




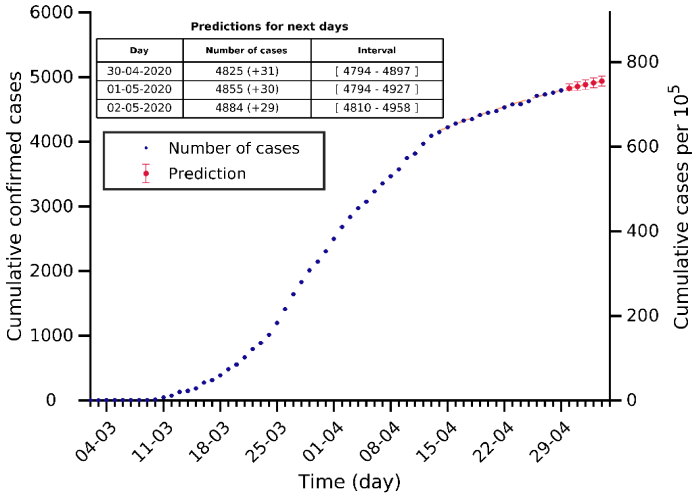


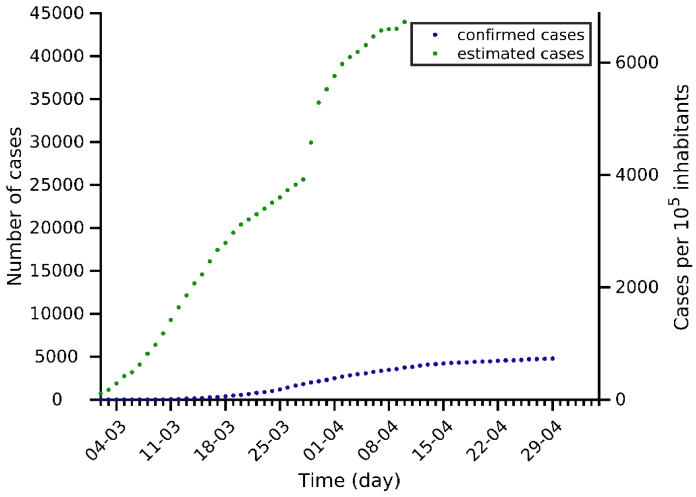


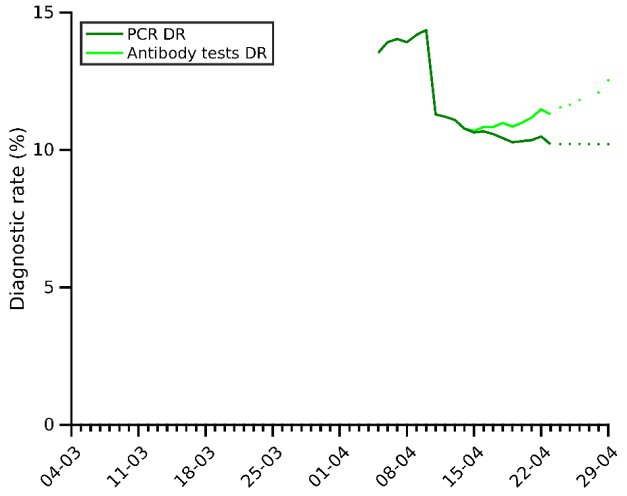


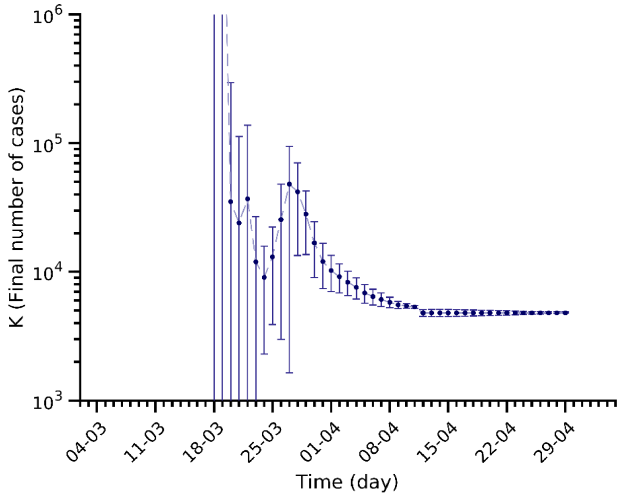


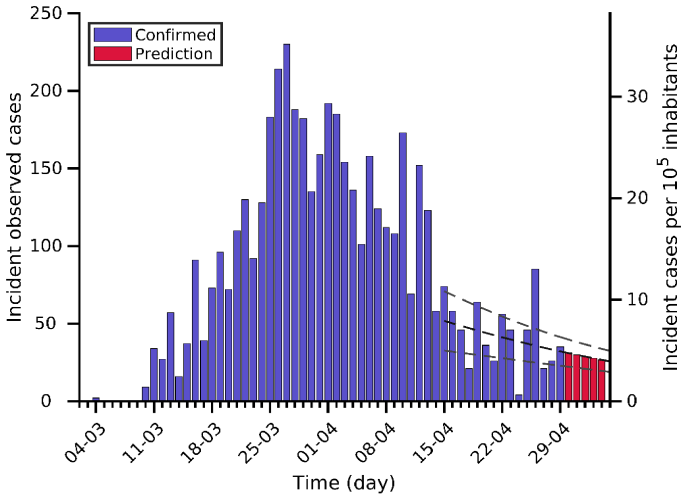
Navarra 29-04-2020. Population: 0.7M. Current cumulated incidence: 733/10⁵

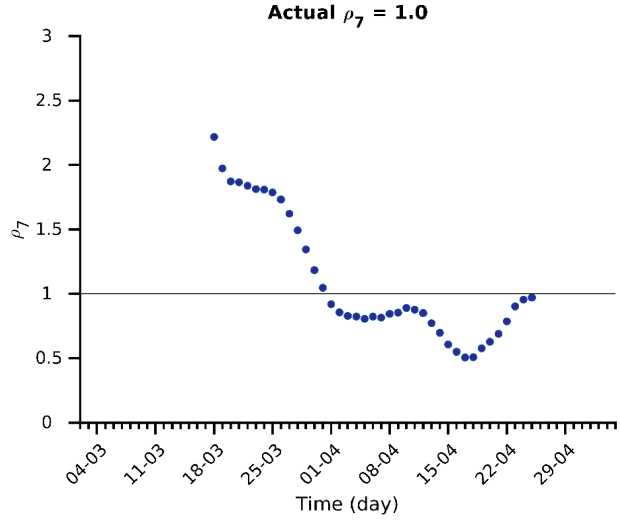


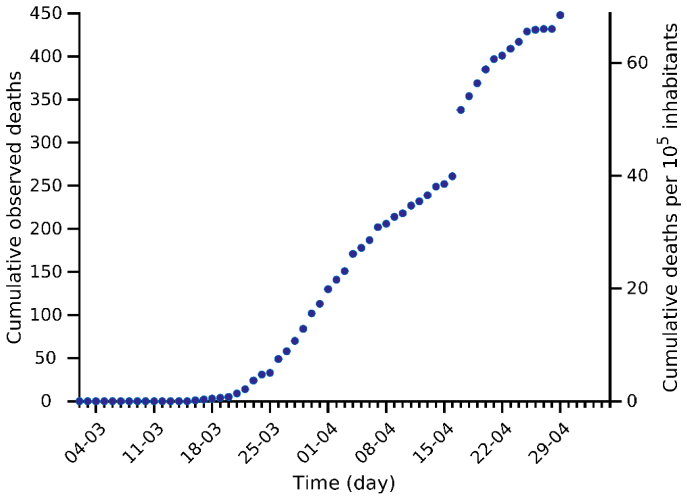


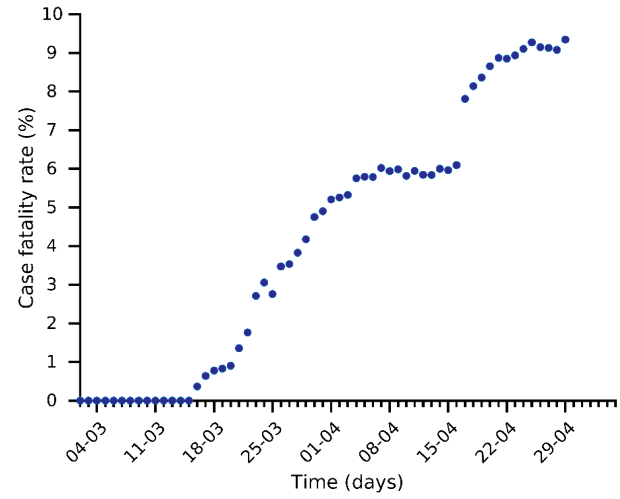




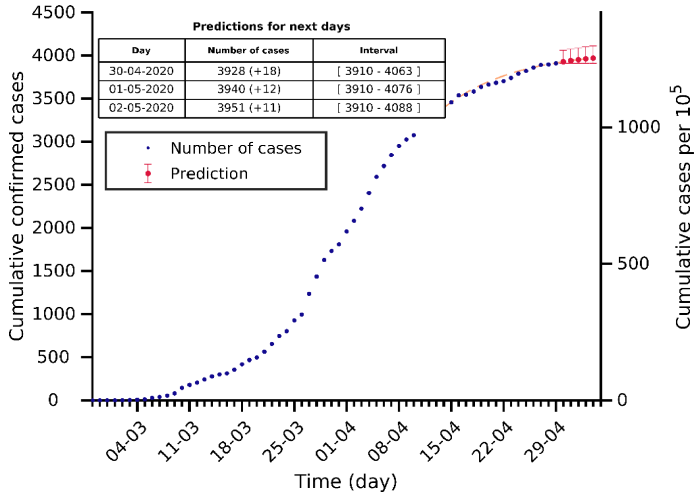


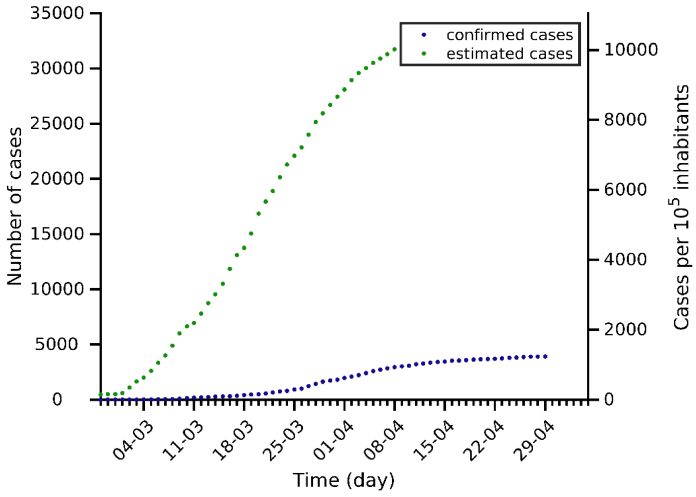


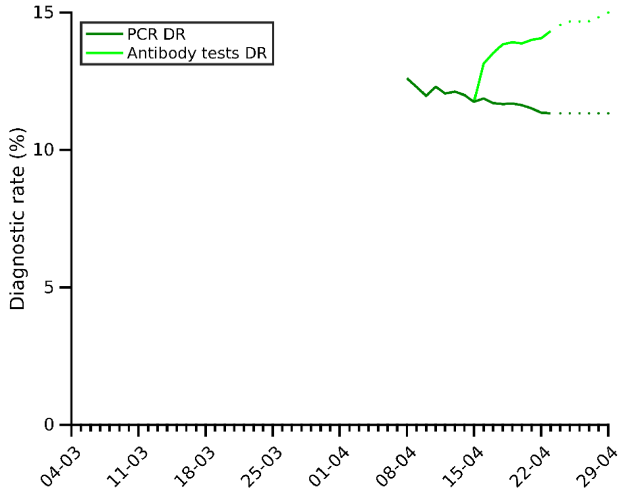


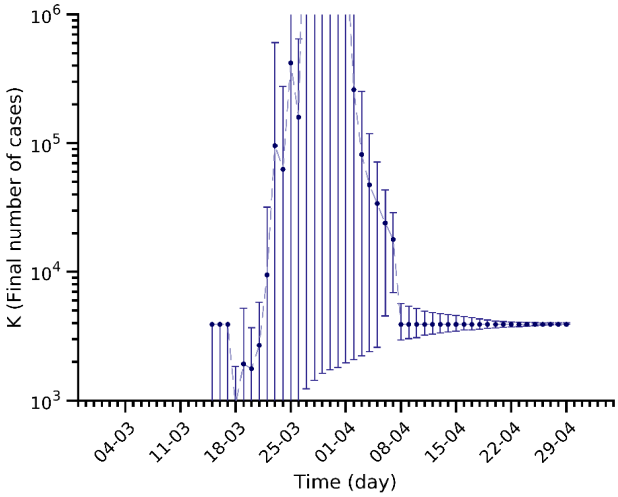


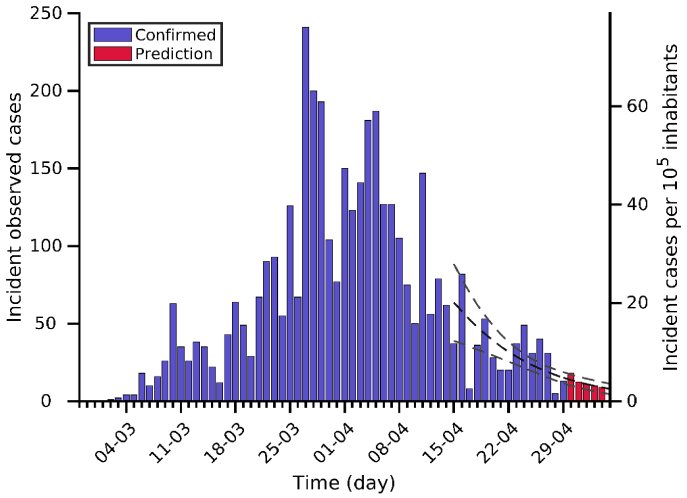
La Rioja 29-04-2020. Population: 0.3M. Current cumulated incidence: 1234/10^5

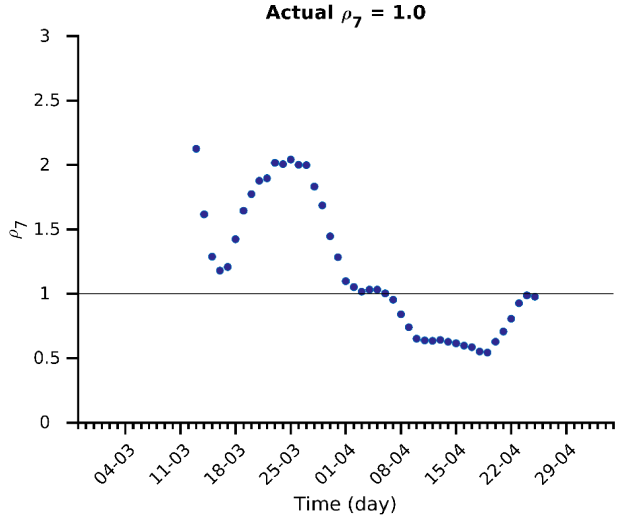


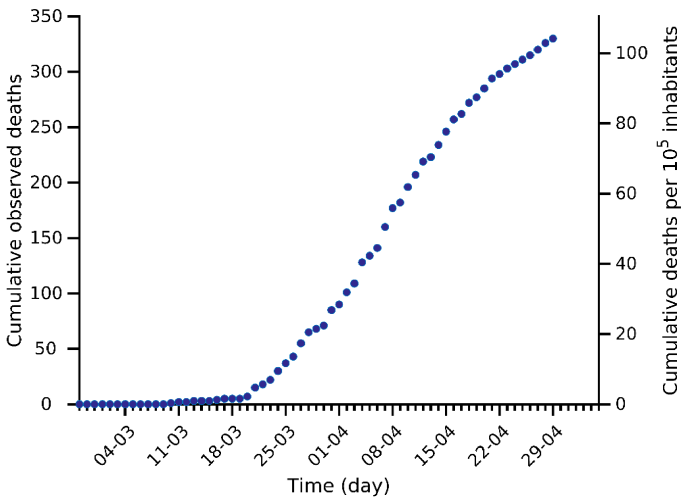


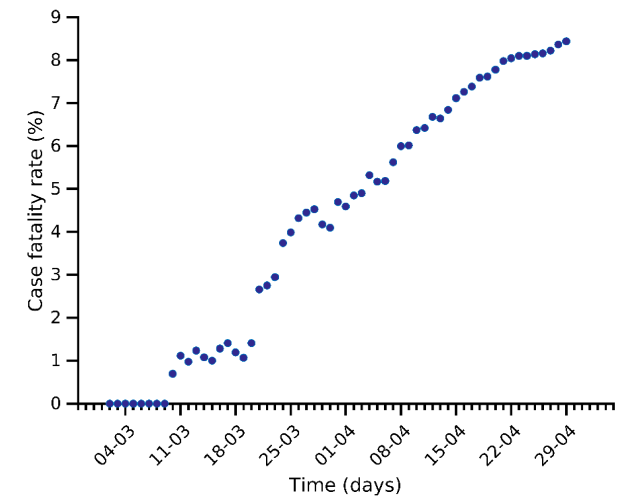




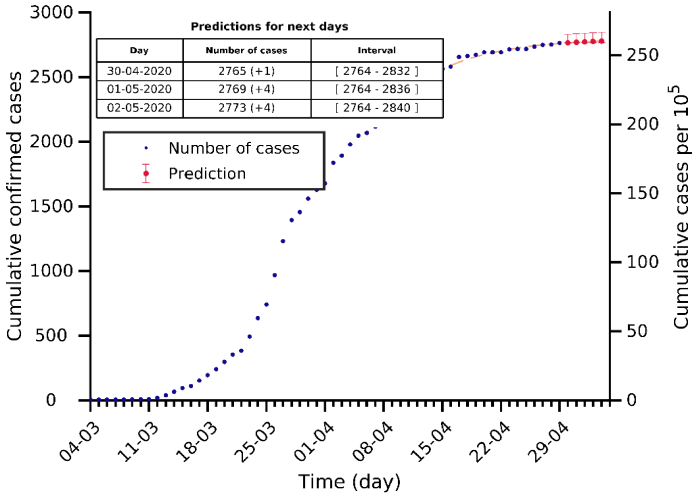


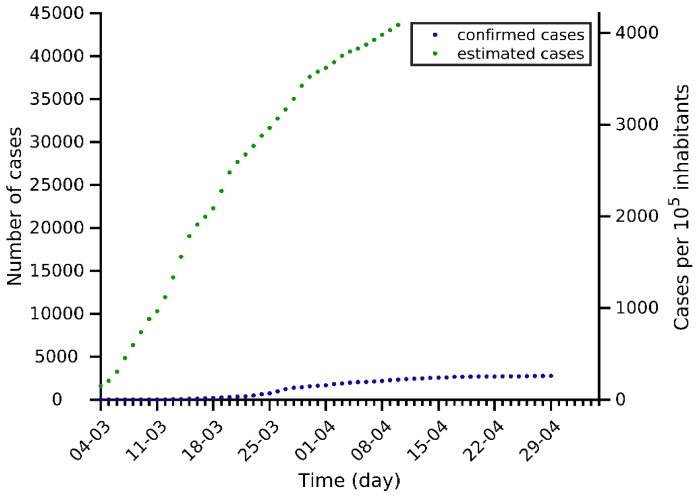


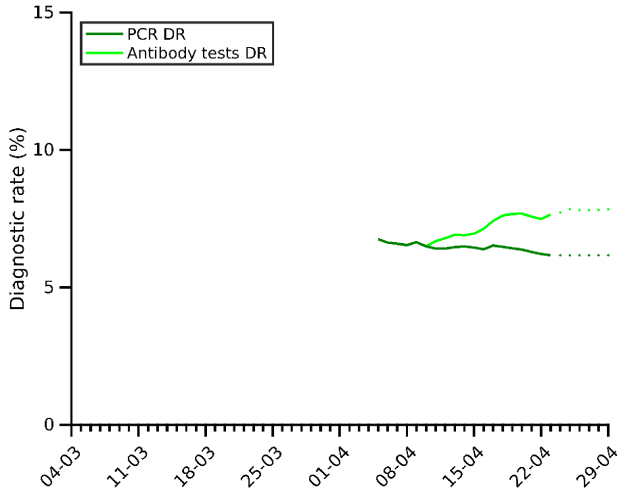


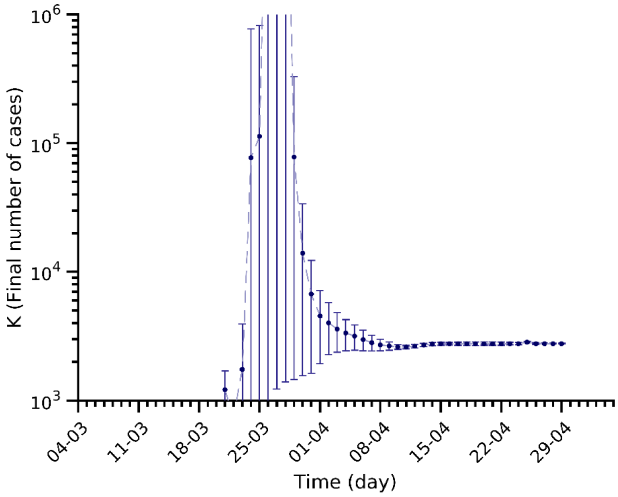


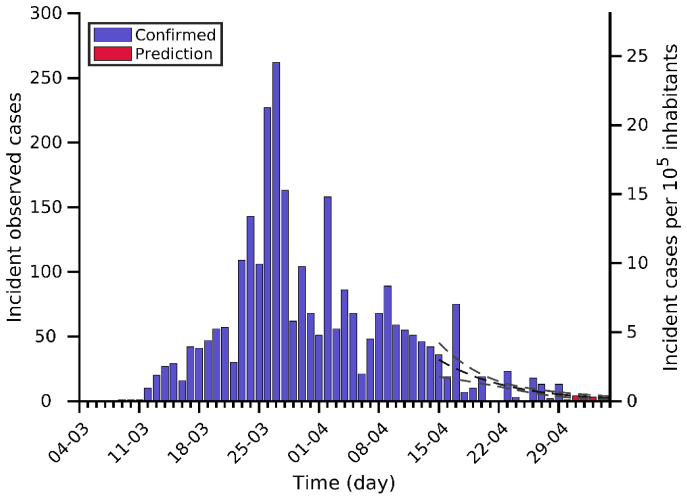
Extremadura 29-04-2020. Population: 1.1M. Current cumulated incidence: 259/10^5

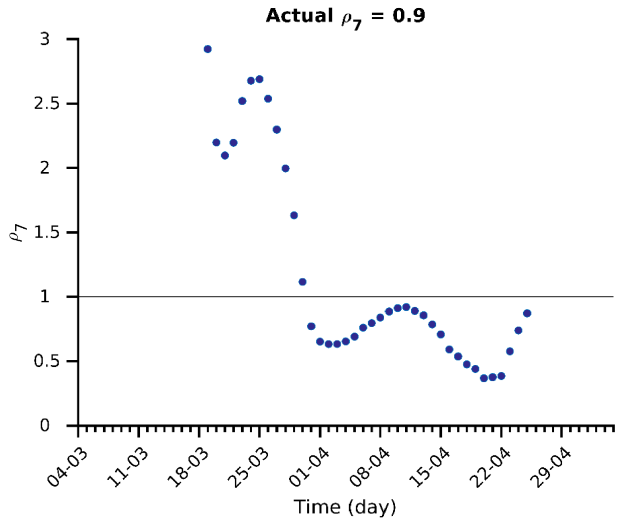


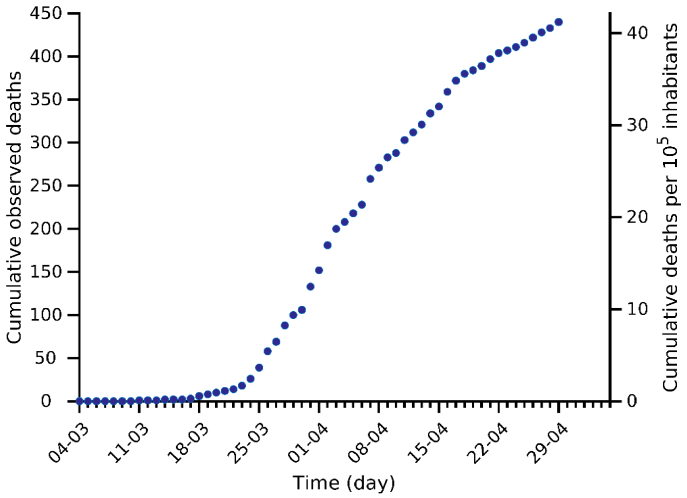


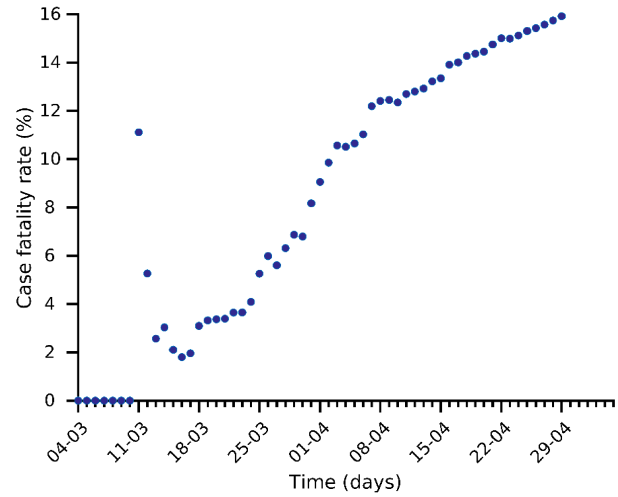




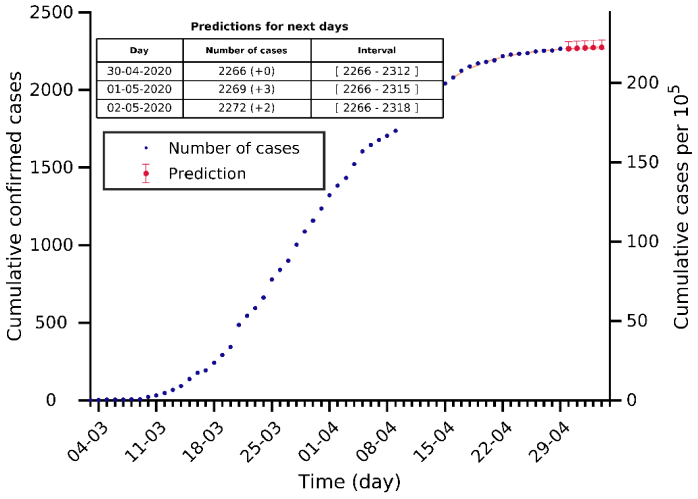


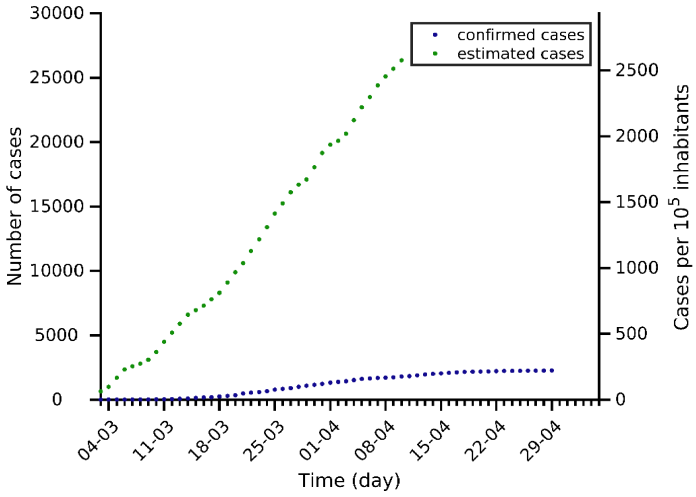


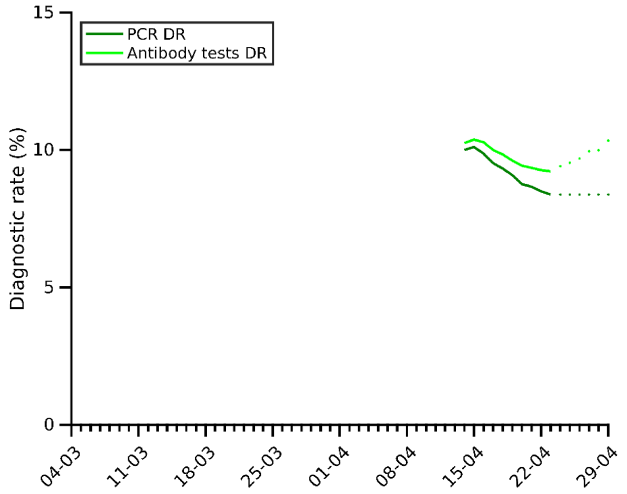


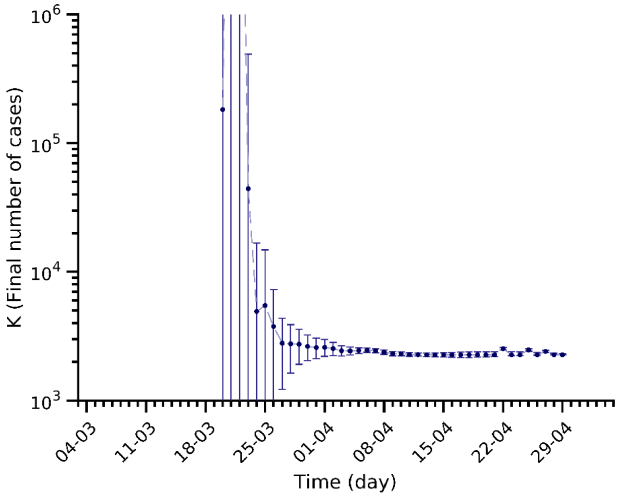


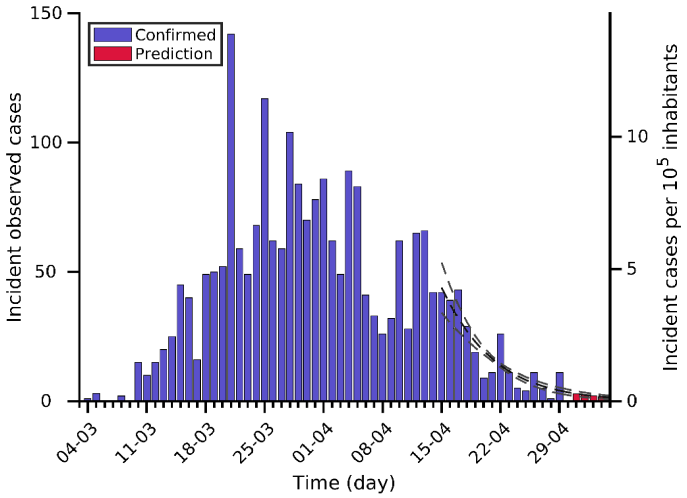
Asturias 29-04-2020. Population: 1.0M. Current cumulated incidence: 222/10⁵

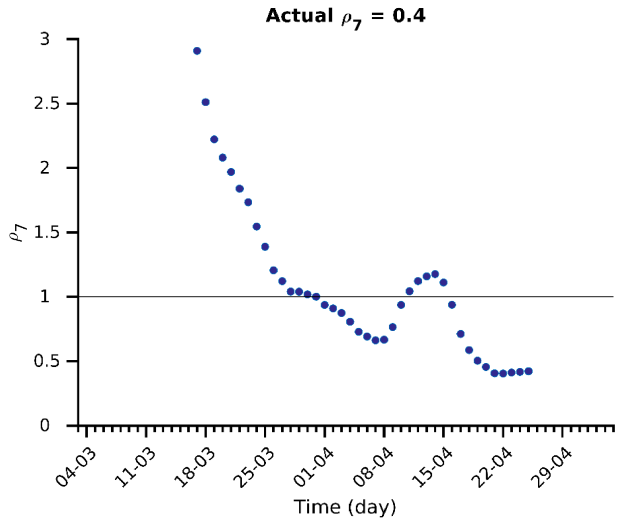


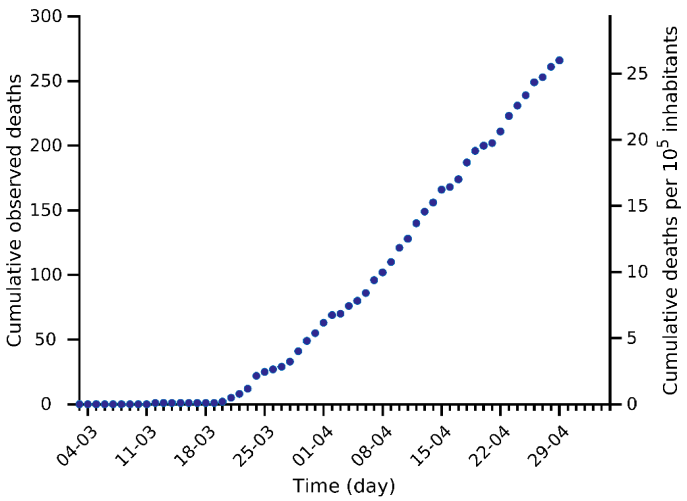


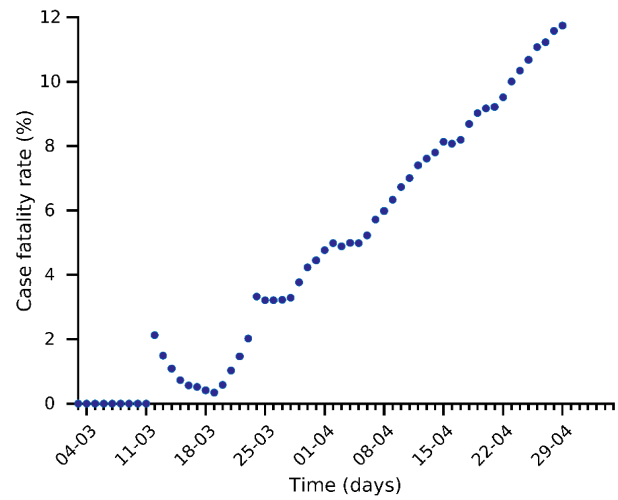




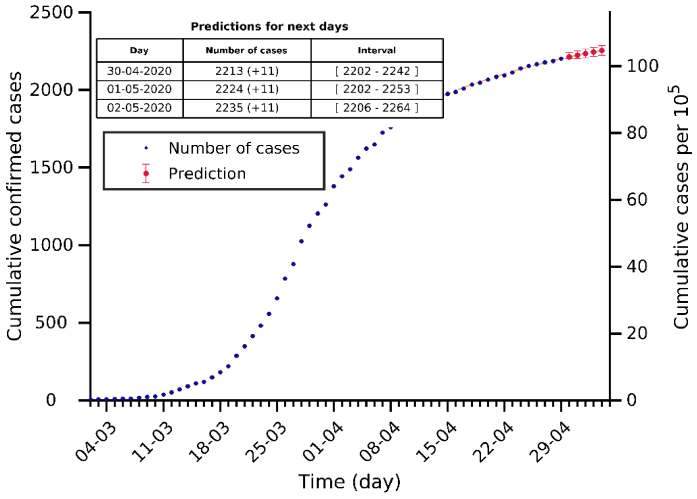


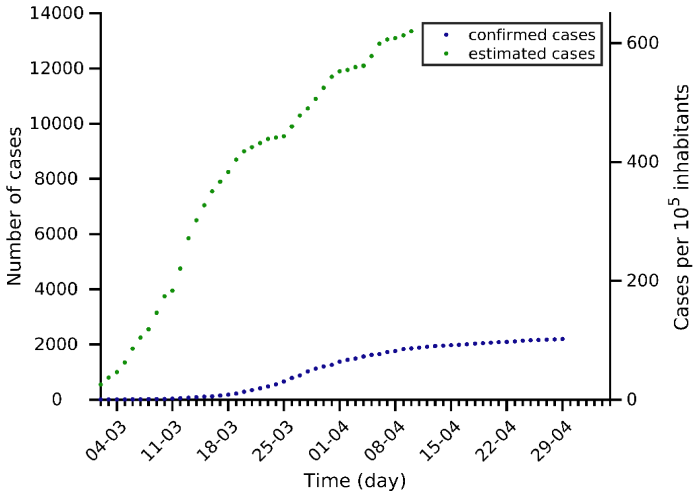


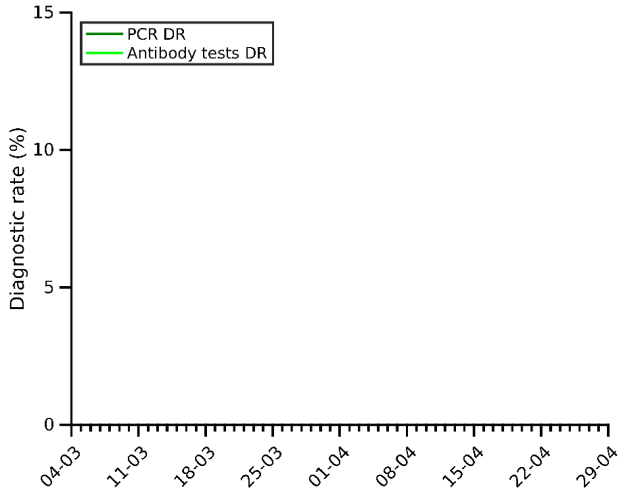


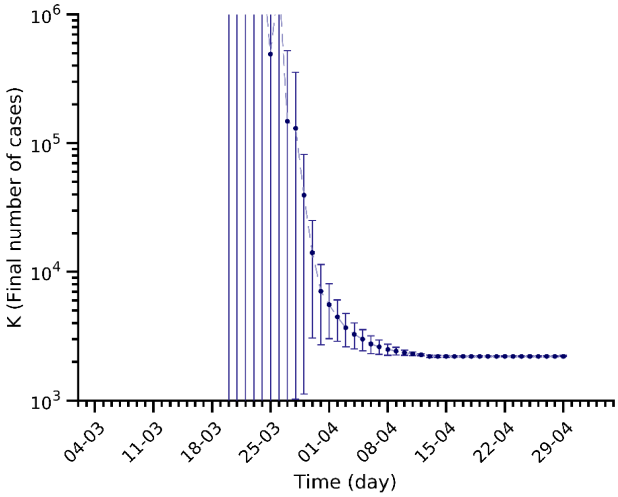


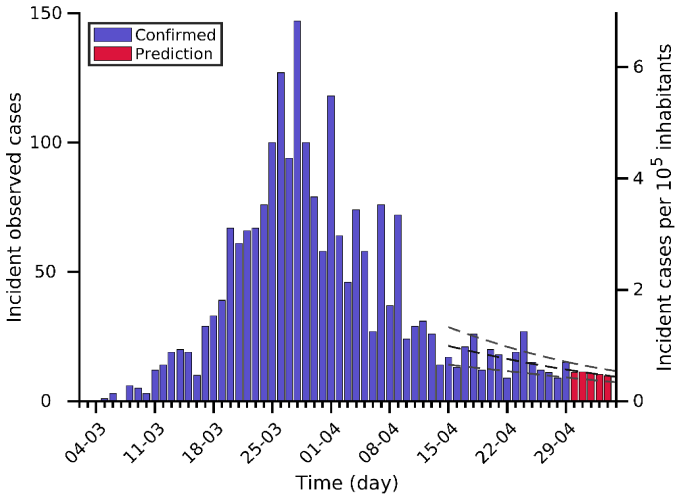
Canarias 29-04-2020. Population: 2.2M. Current cumulated incidence: 102/10⁵

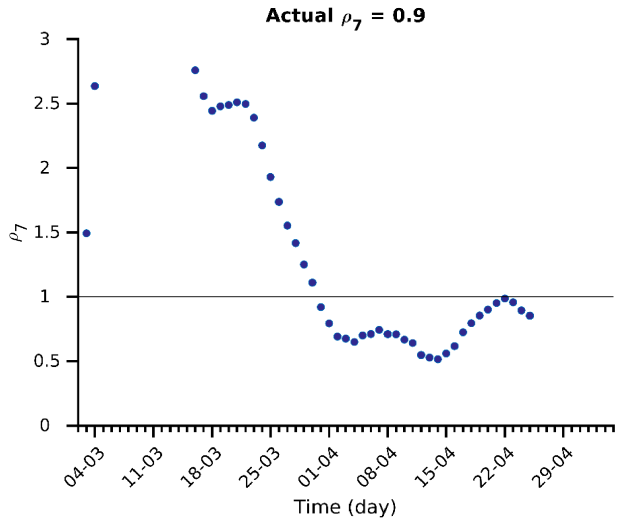


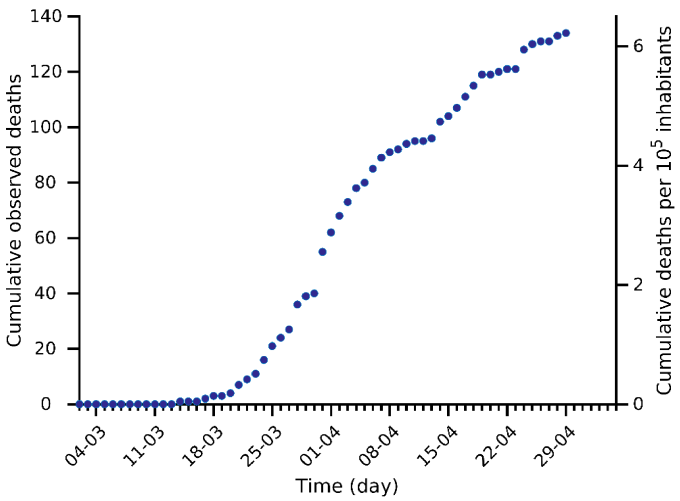


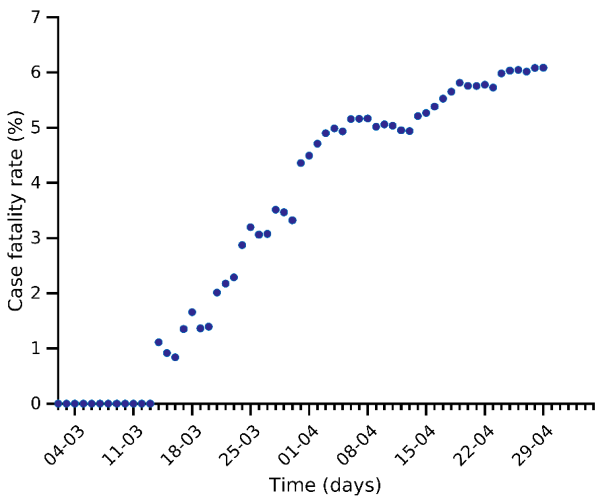




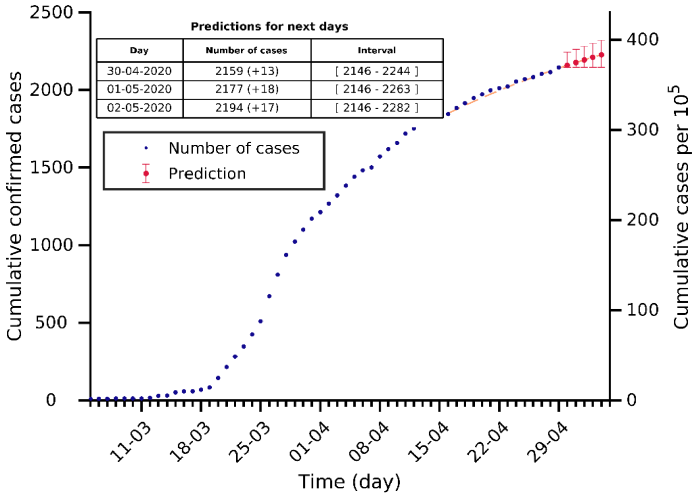


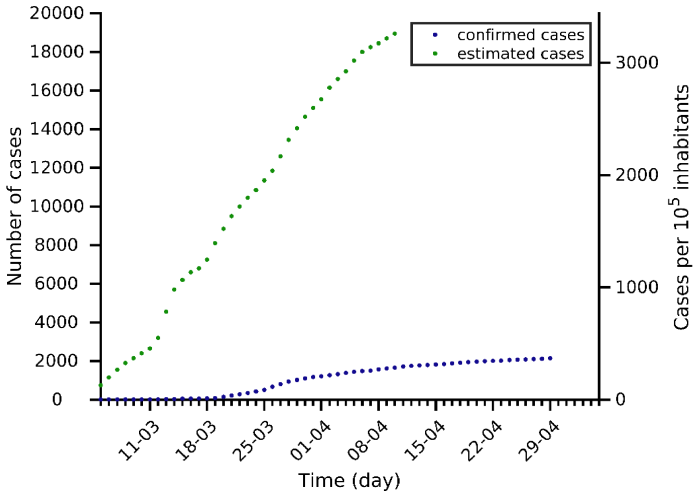


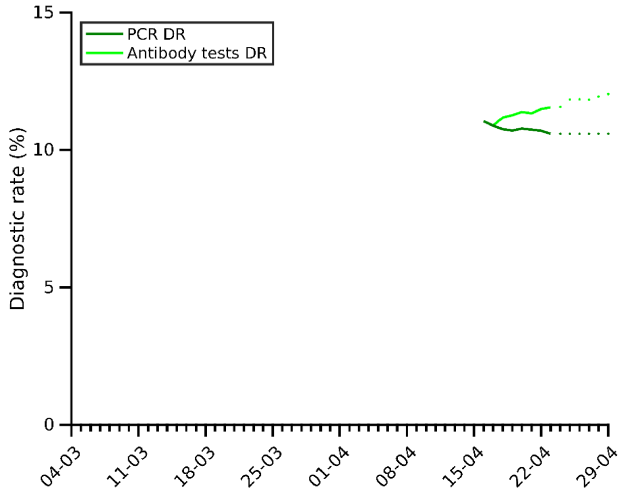


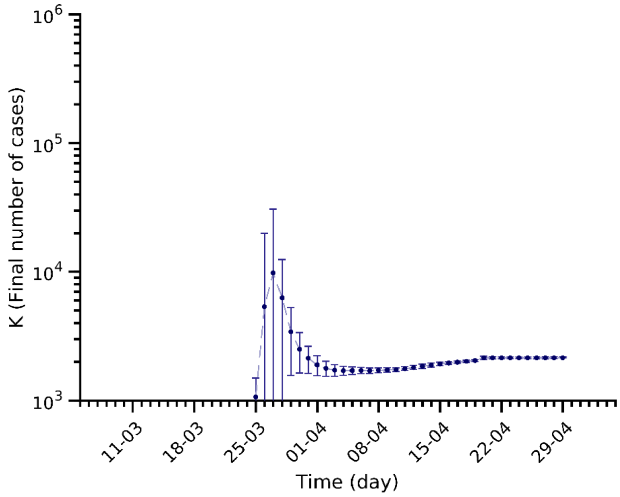


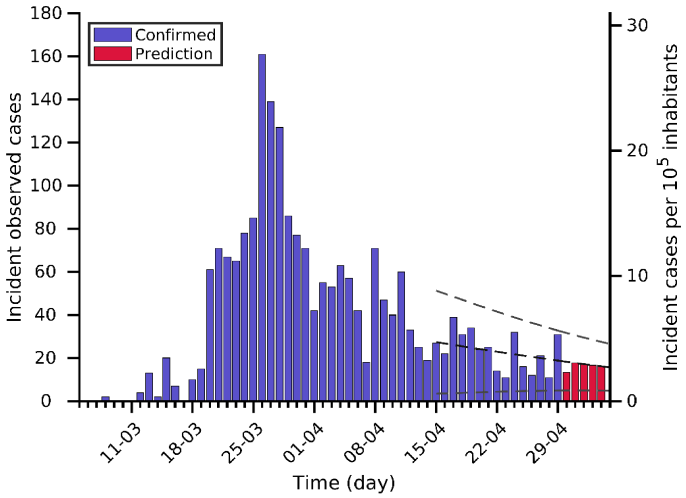
Cantabria 29-04-2020. Population: 0.6M. Current cumulated incidence: 369/10⁵

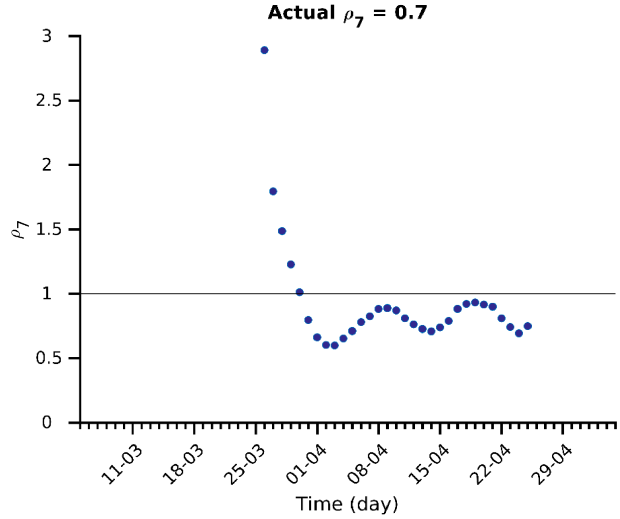


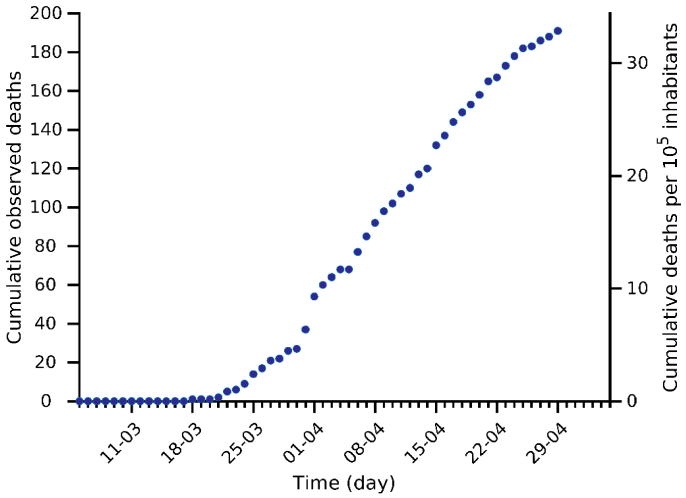


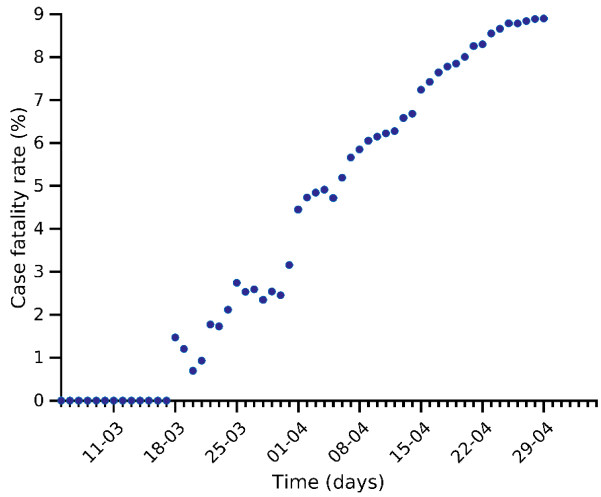




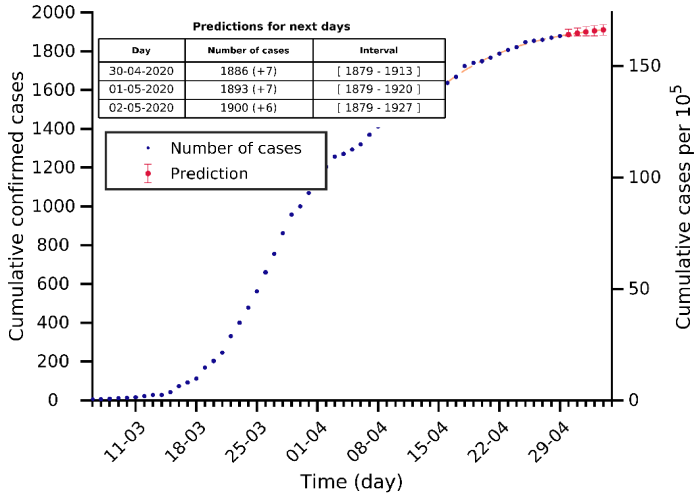


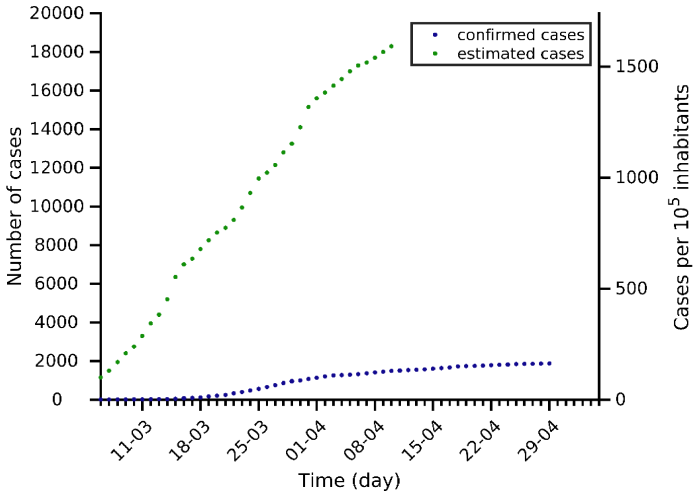


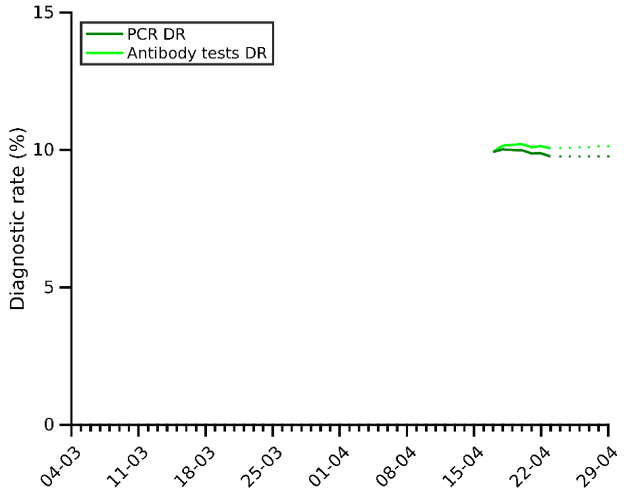


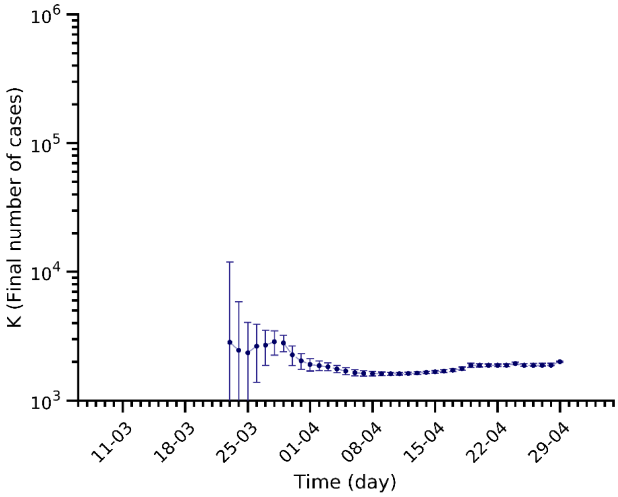


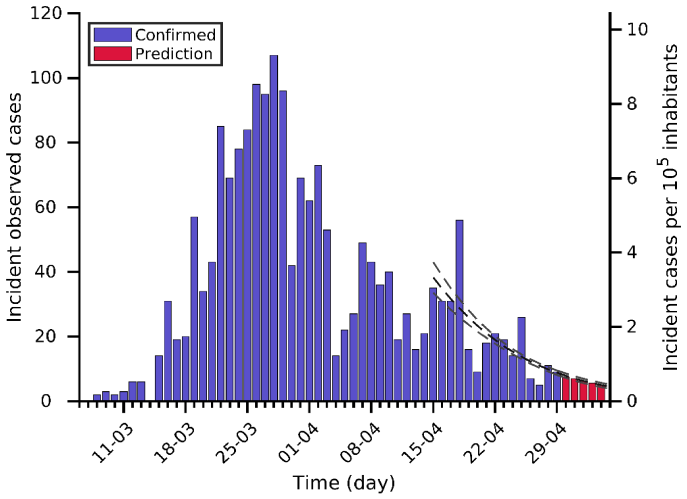
Baleares 29-04-2020. Population: 1.1M. Current cumulated incidence: 163/10^5

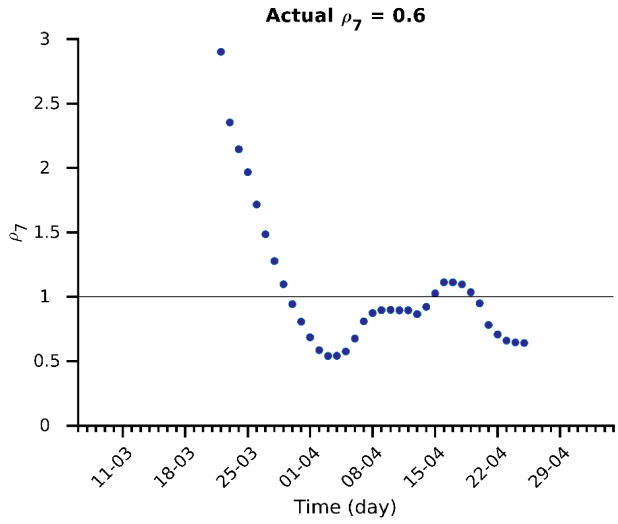


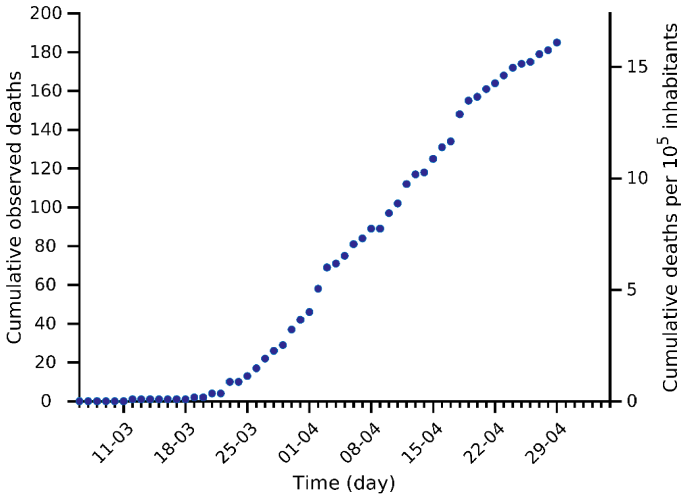


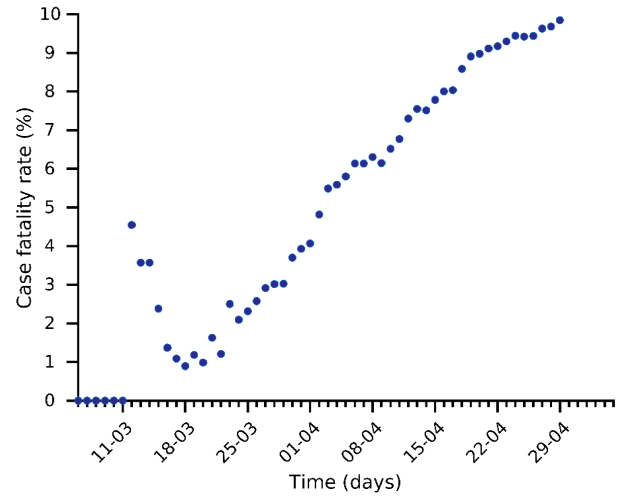




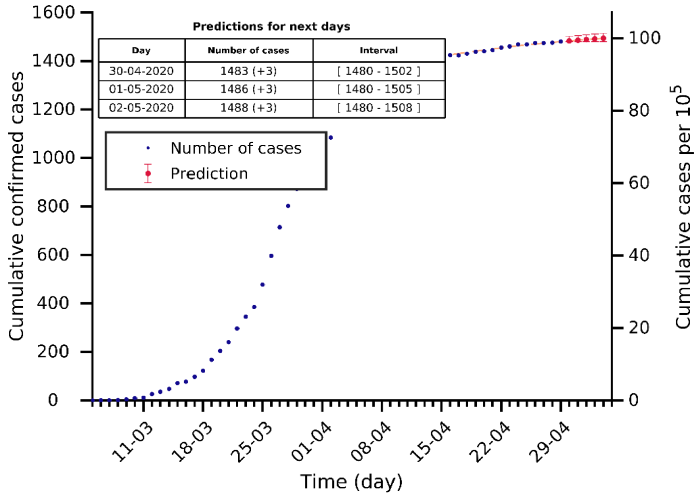


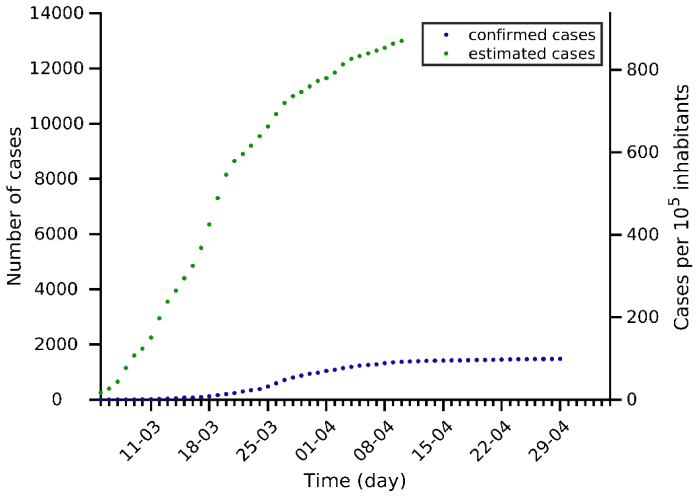


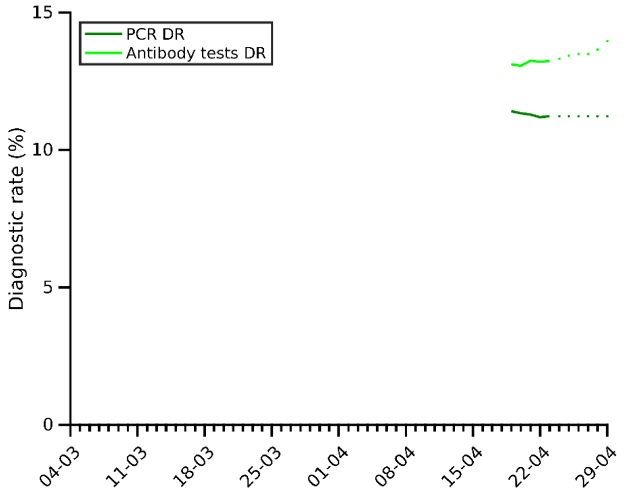


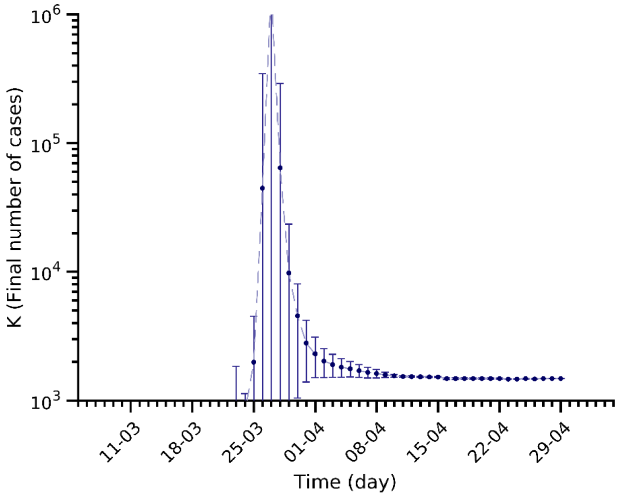


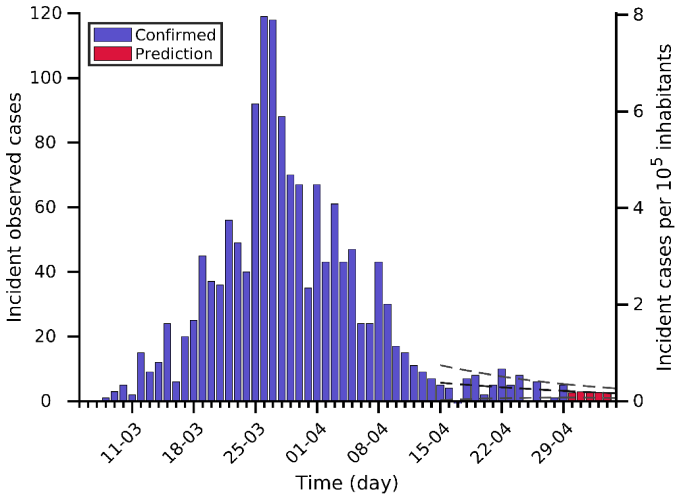
Murcia 29-04-2020. Population: 1.5M. Current cumulated incidence: 99/10^5

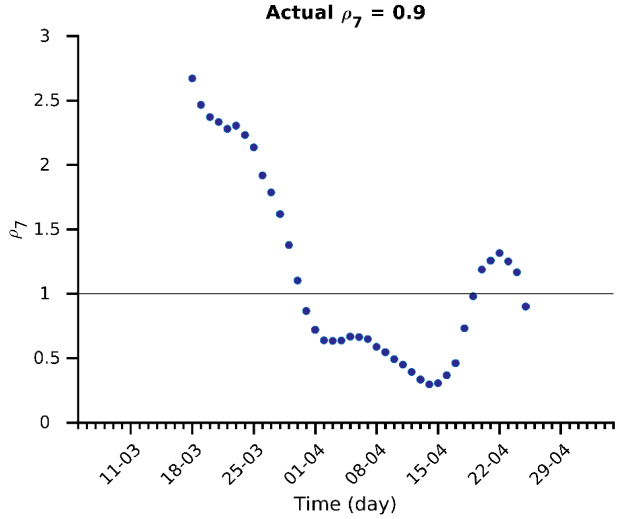


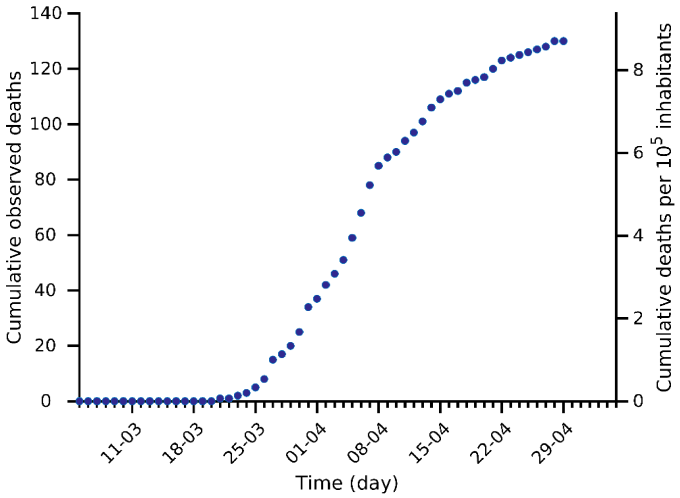


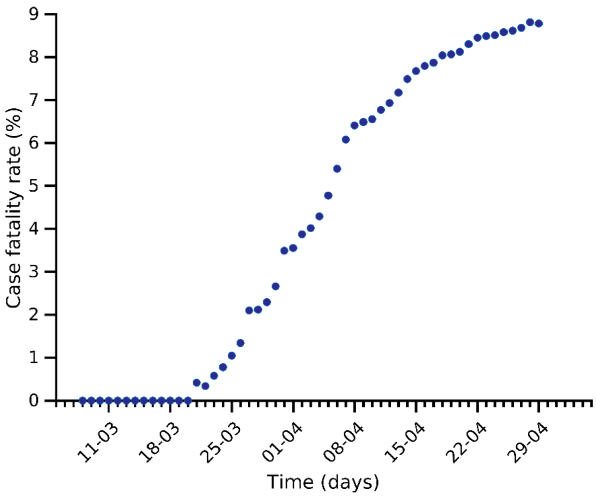








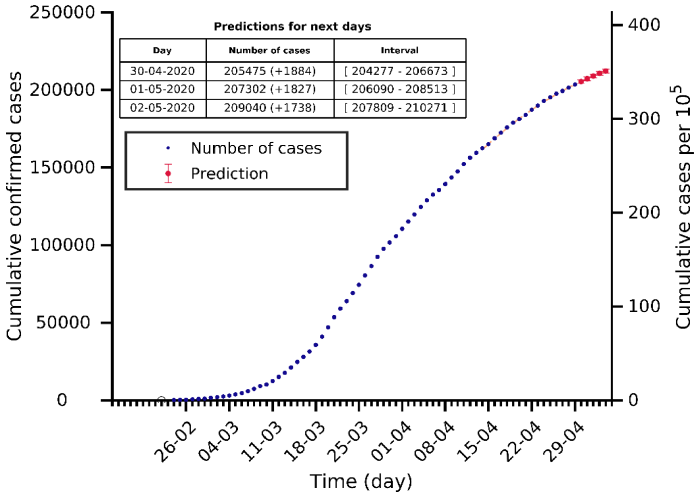


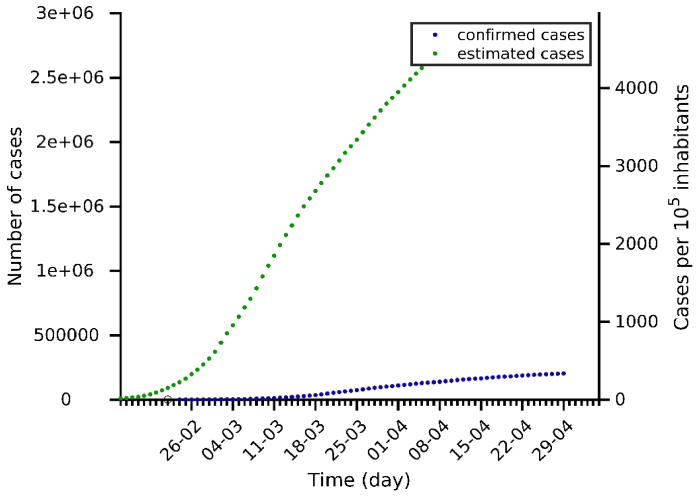


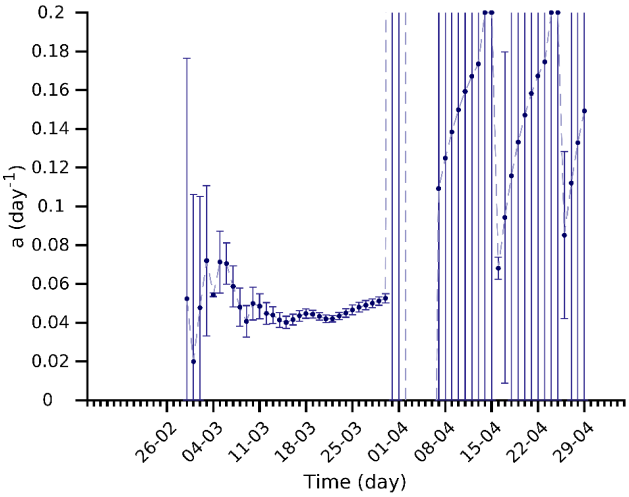
(4) Analysis and prediction of COVID-19 for Italy and its regions

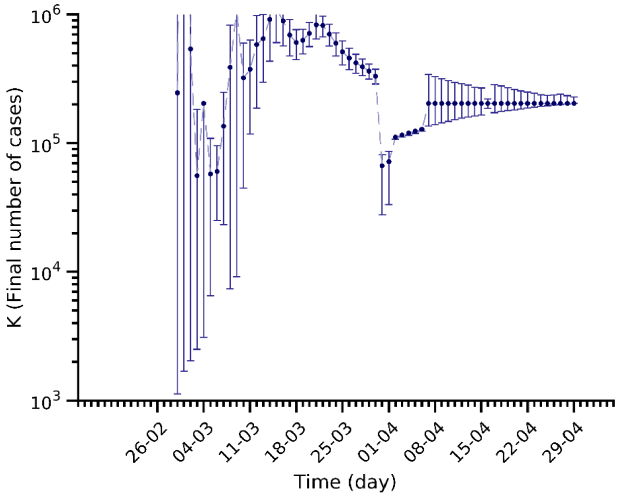
Data obtained from: https://github.com/pcm-dpc/COVID-19/tree/master/dati-andamento-nazionale

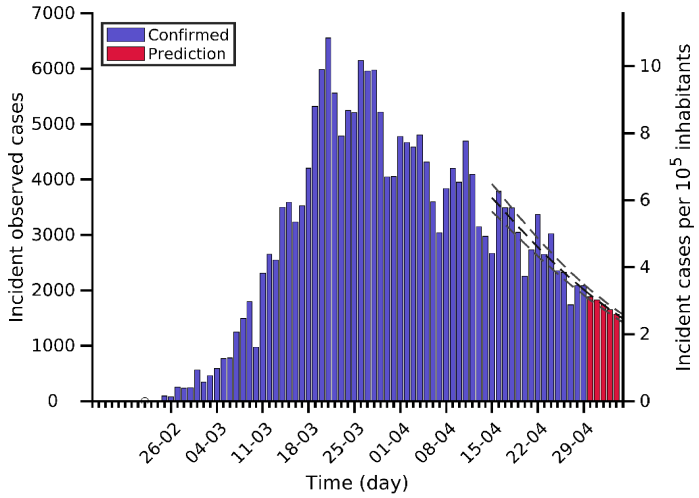
Italy 29-04-2020. Population: 60.5M. Current cumulated incidence: $337/10^5$

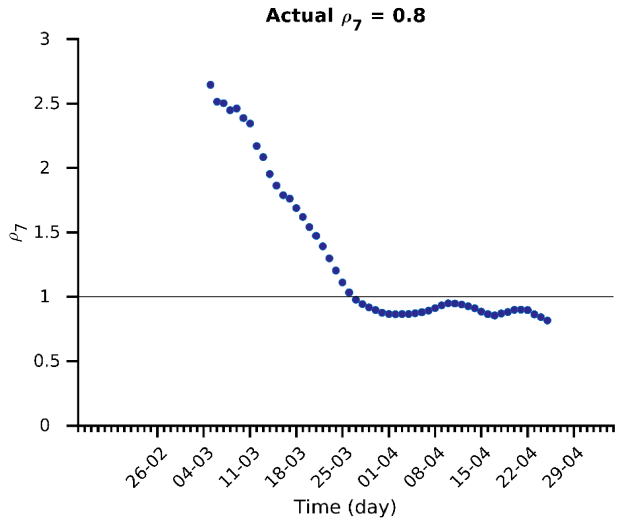


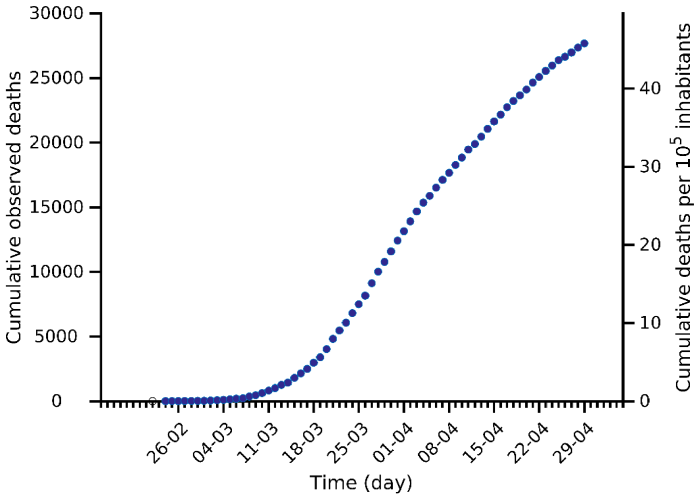


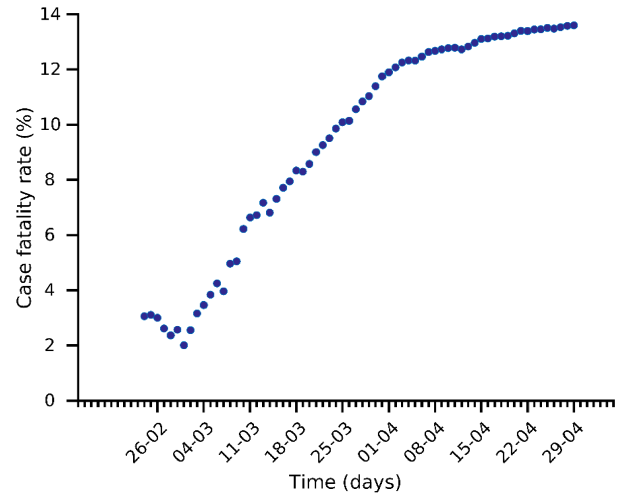




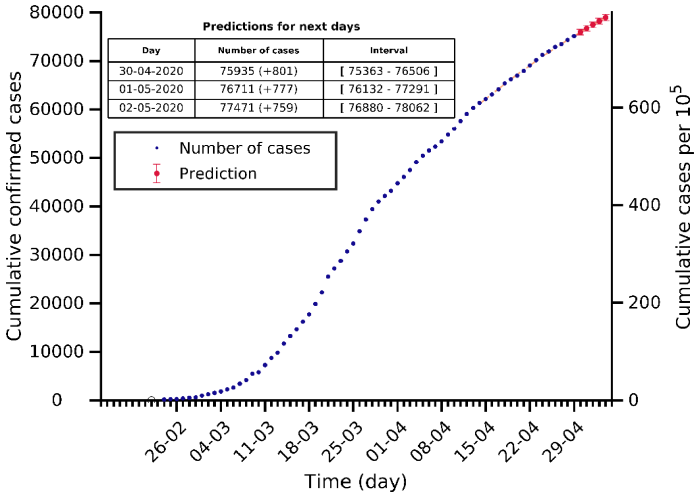


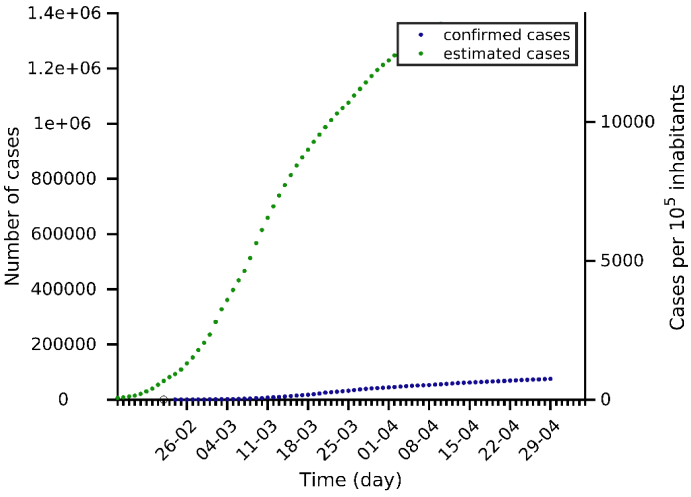


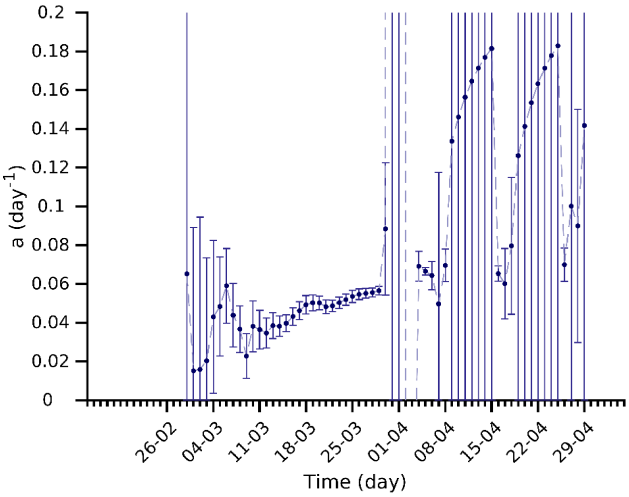


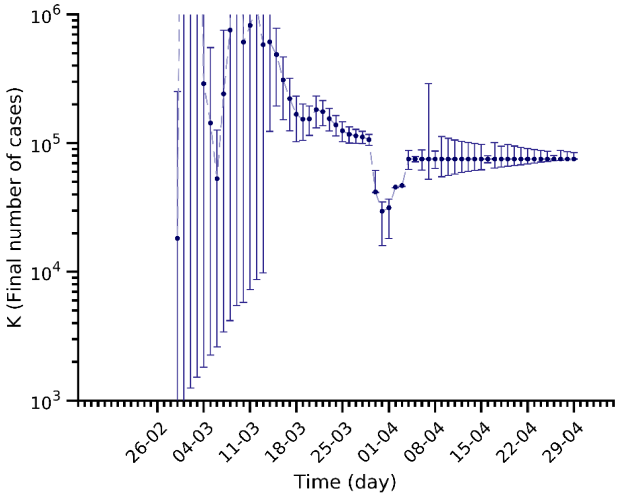


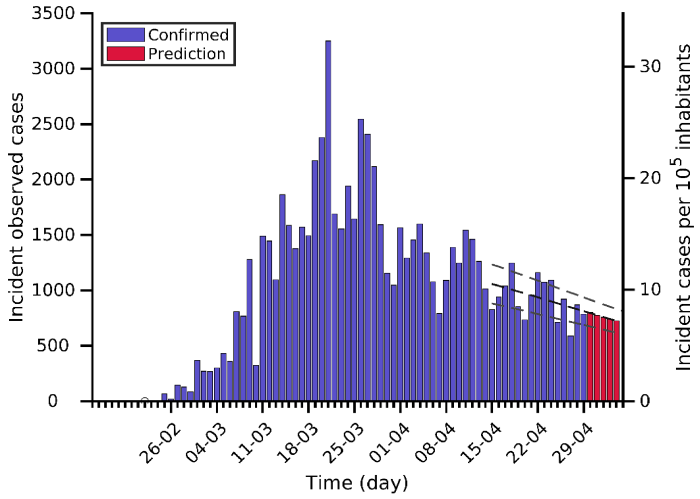
Lombardia 29-04-2020. Population: 10.1M. Current cumulated incidence: 747/10^5

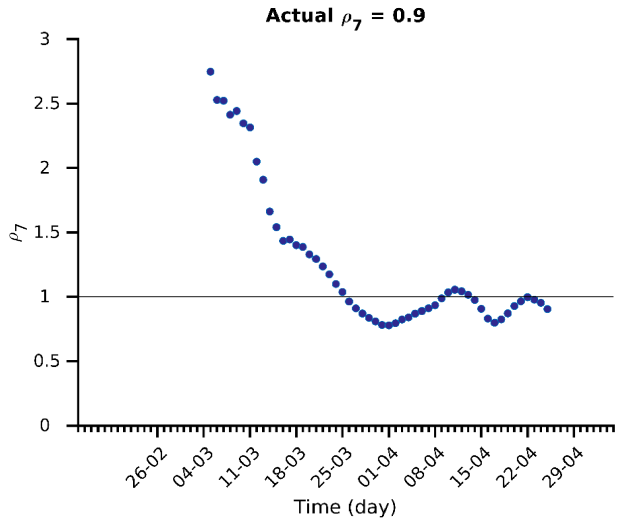


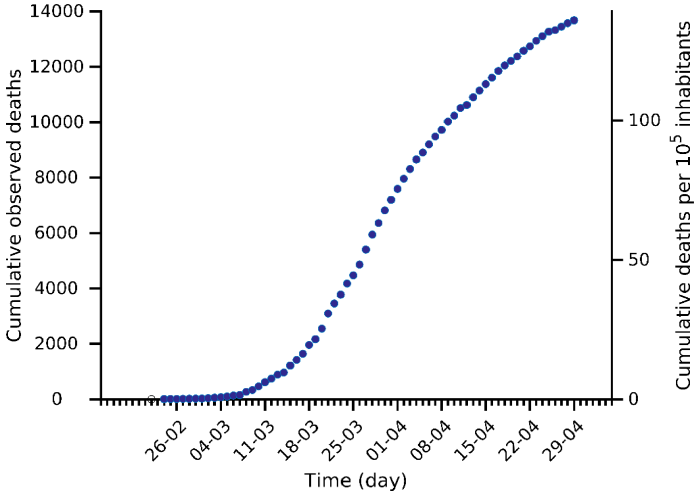


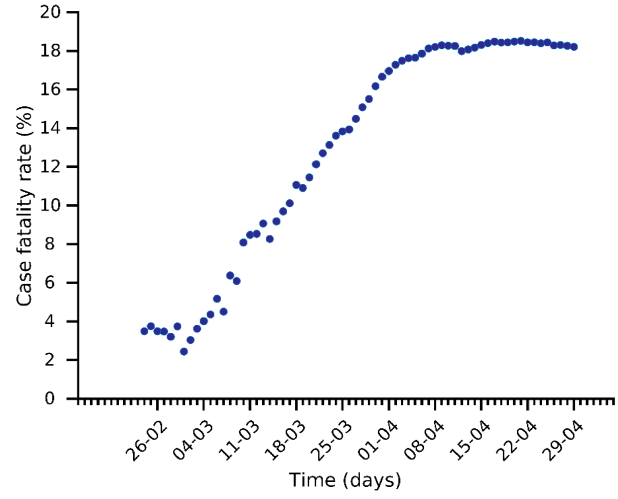




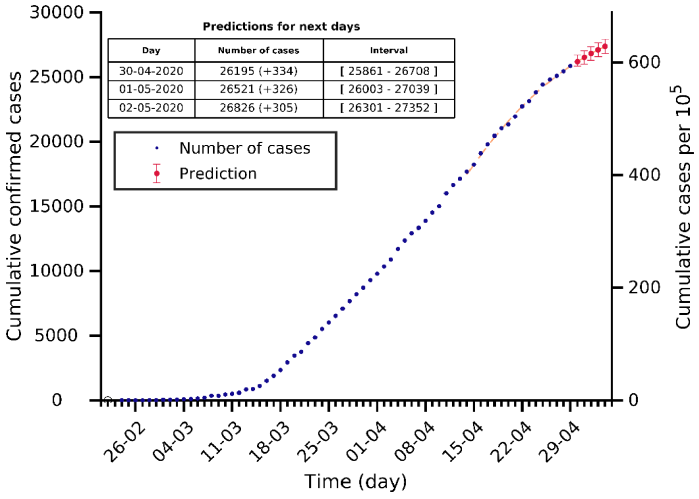


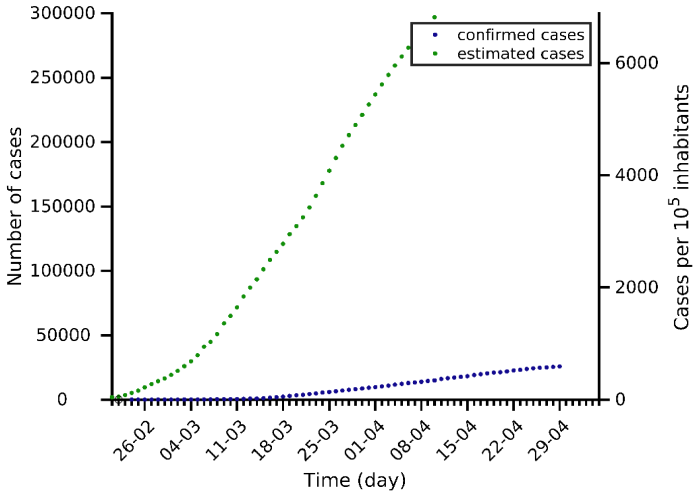


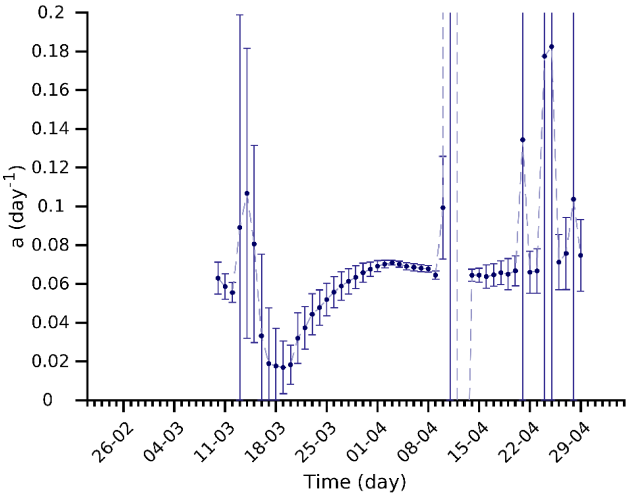


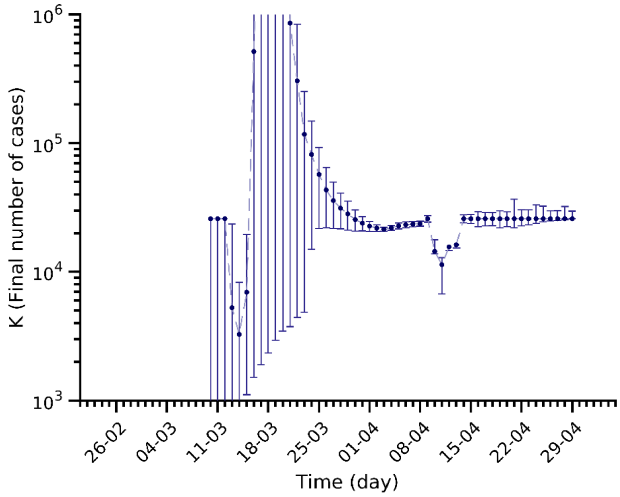


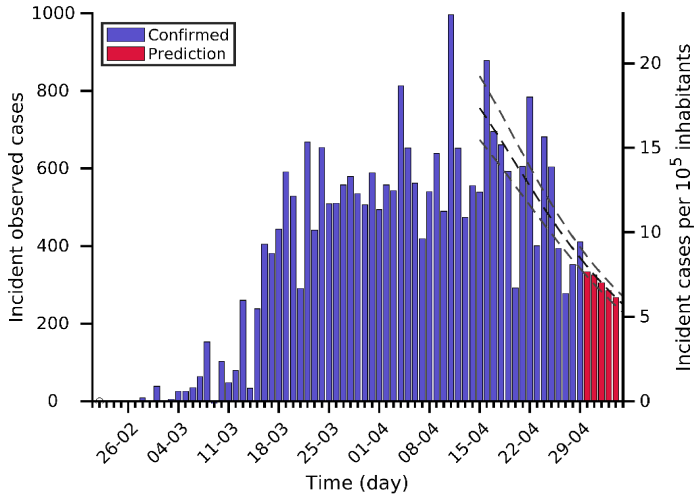
Piemonte 29-04-2020. Population: 4.4M. Current cumulated incidence: 594/10⁵

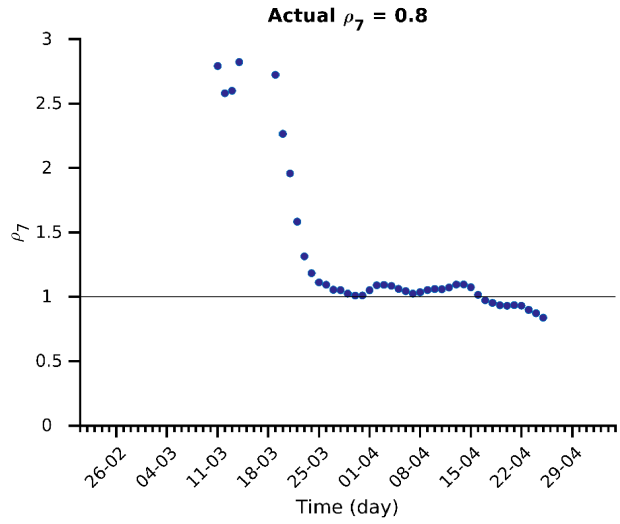


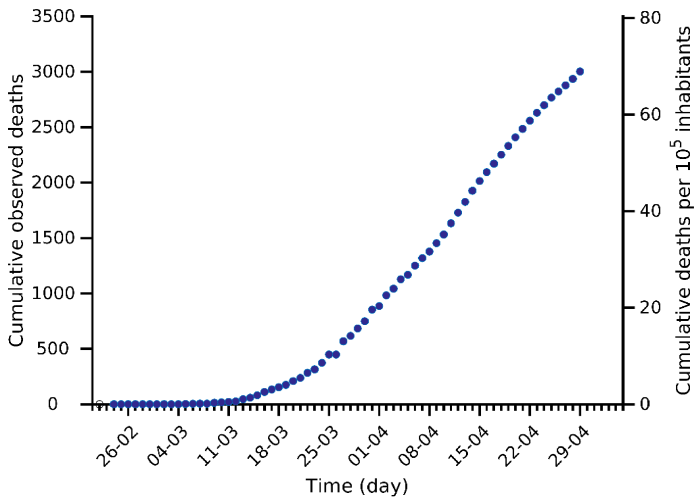


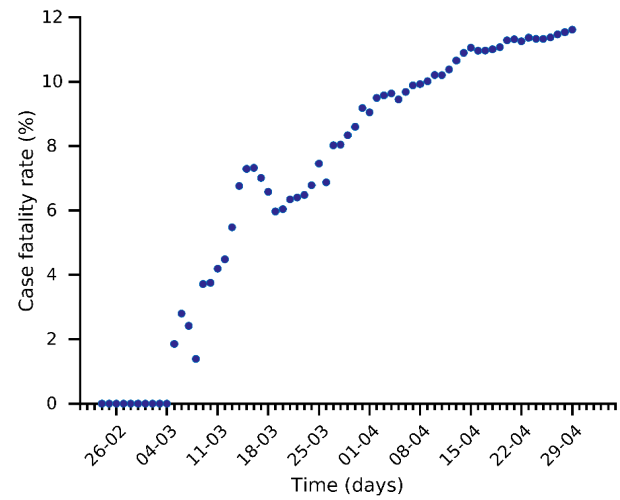




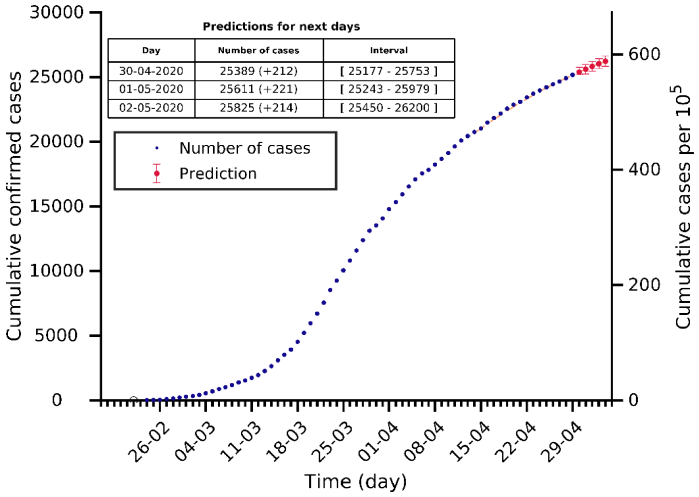


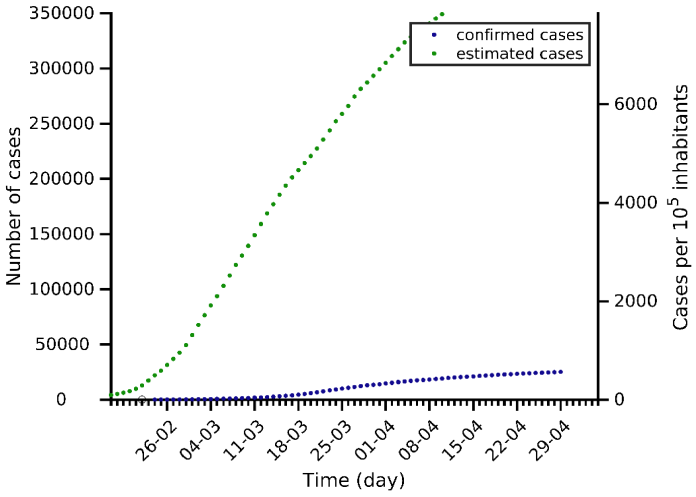


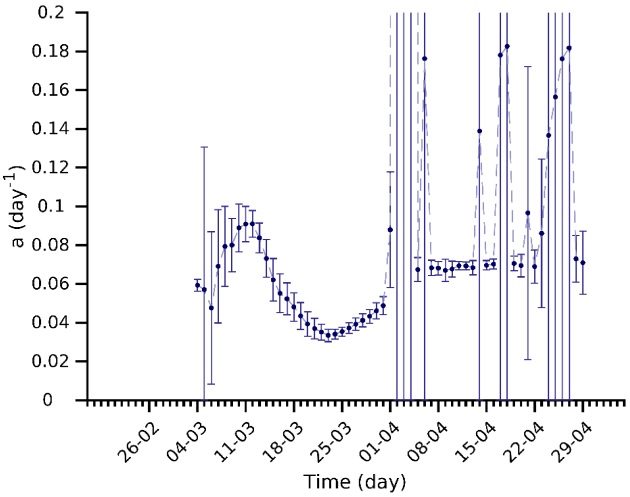


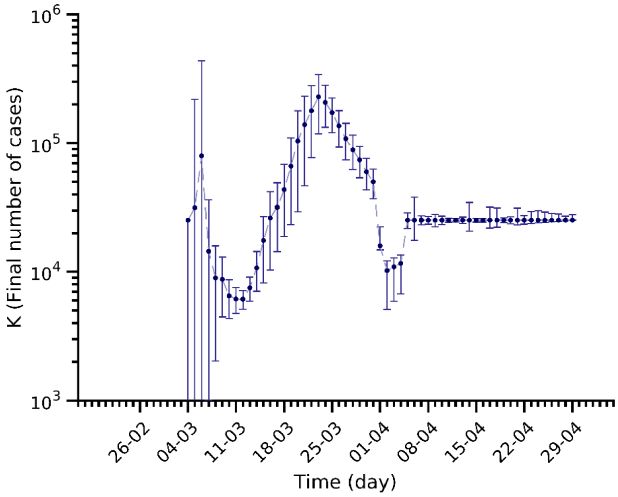


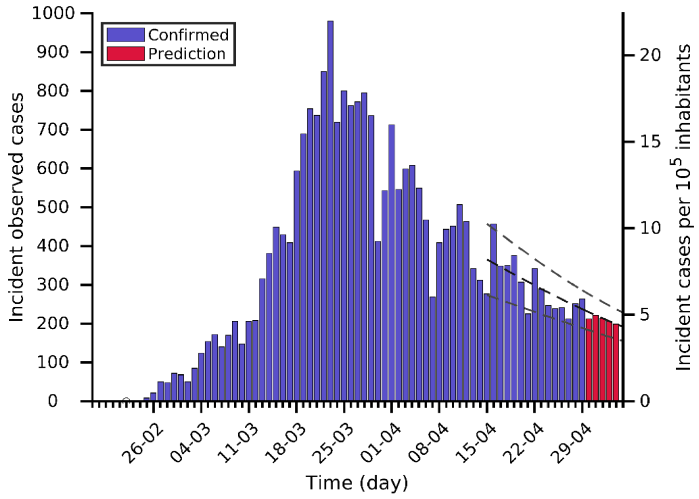
Emilia Romagna 29-04-2020. Population: 4.5M. Current cumulated incidence: 565/1

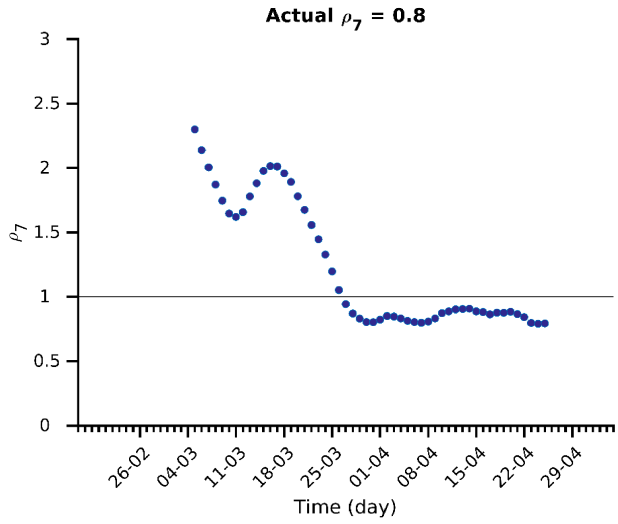


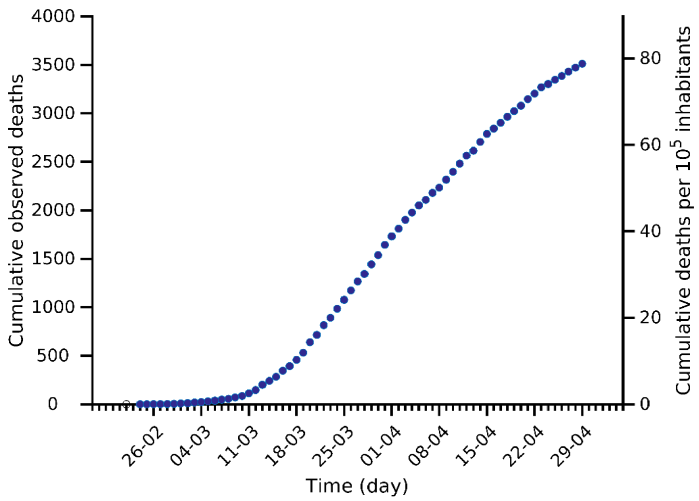


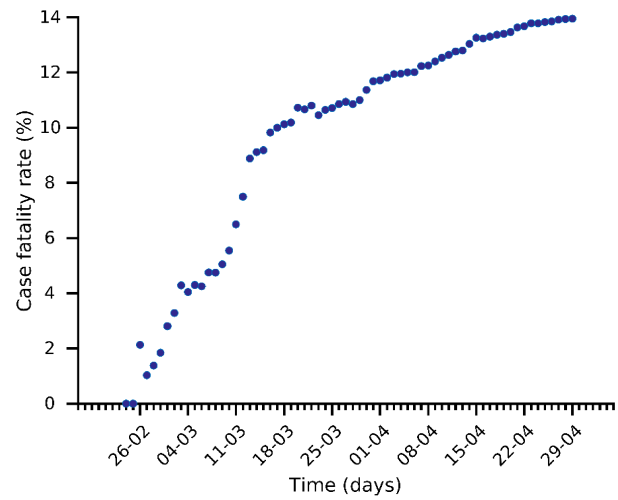




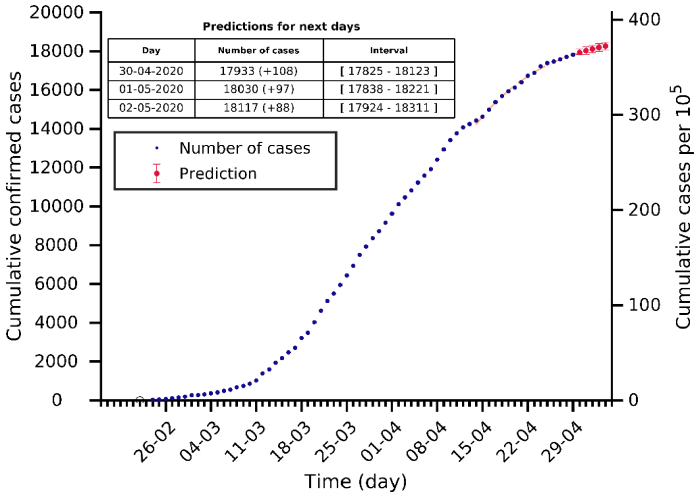


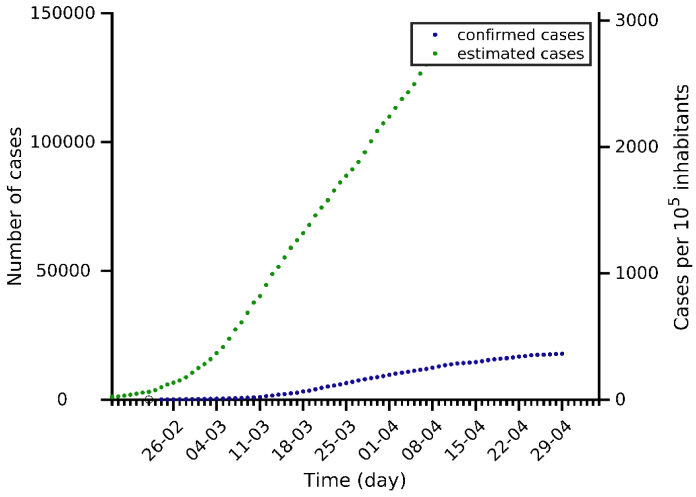


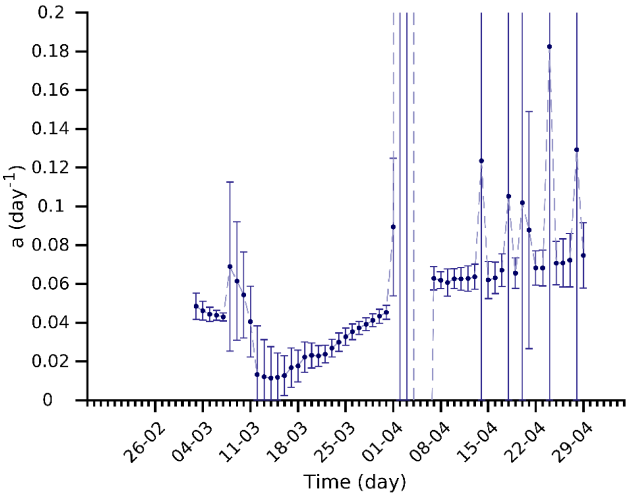


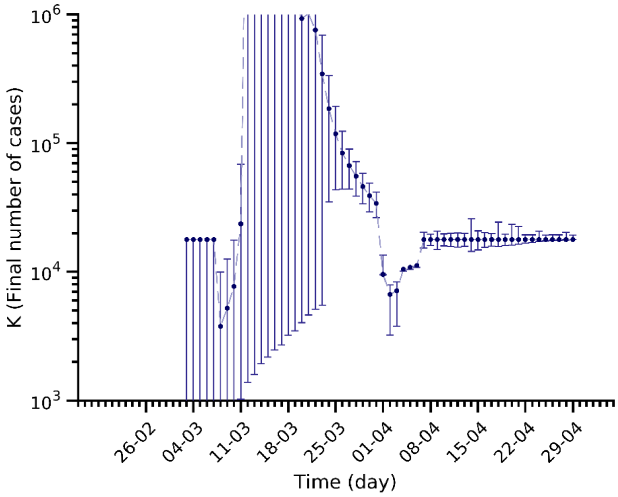


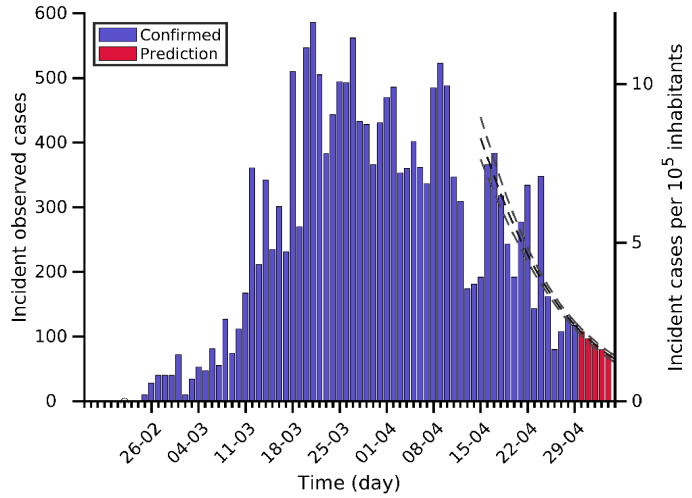
Veneto 29-04-2020. Population: 4.9M. Current cumulated incidence: 363/10^5

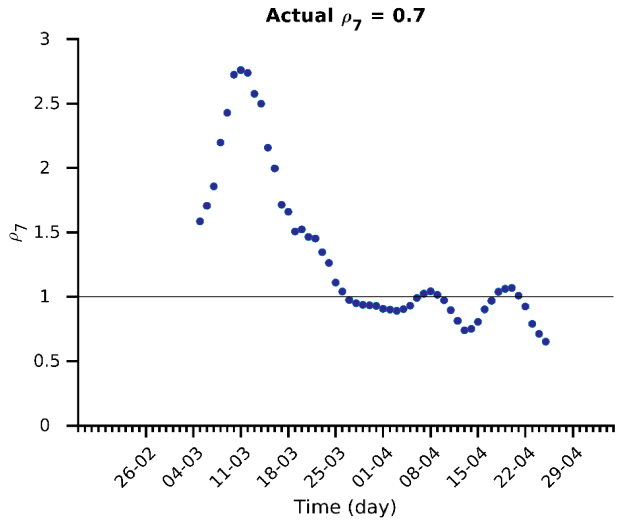


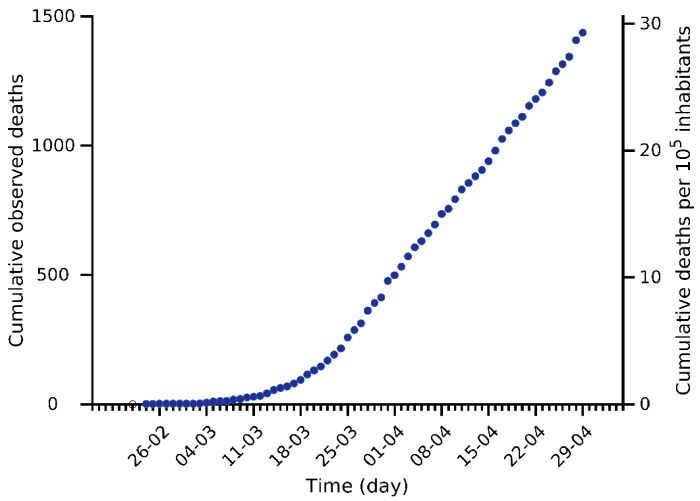


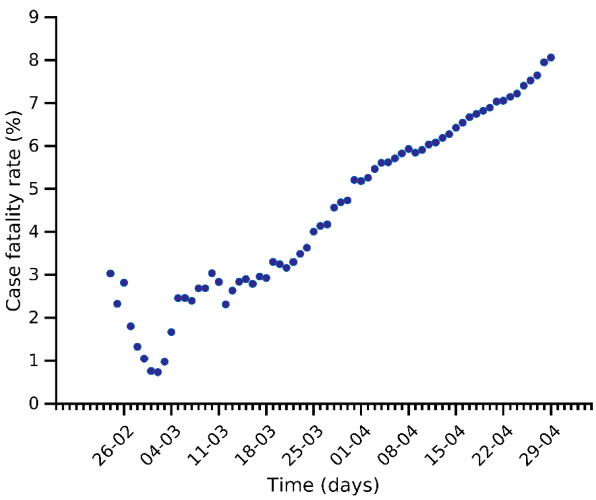




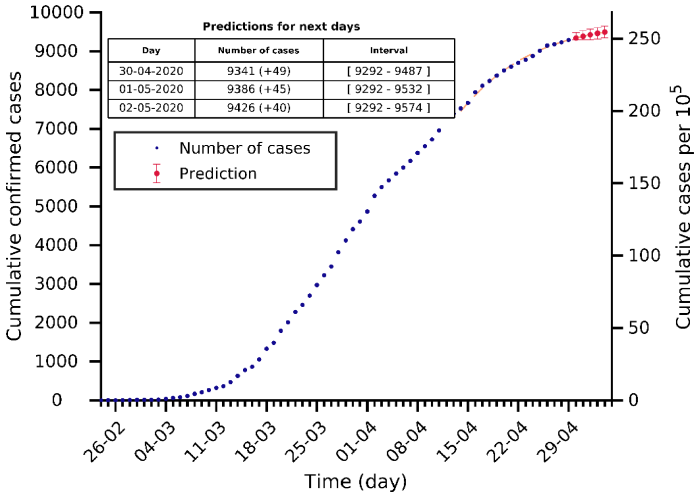


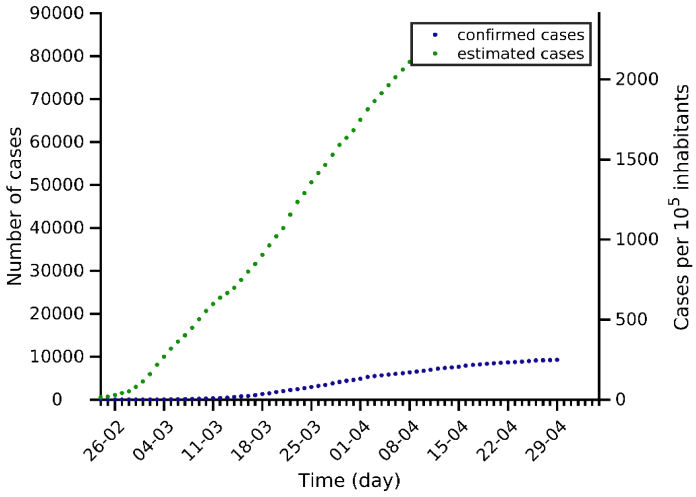


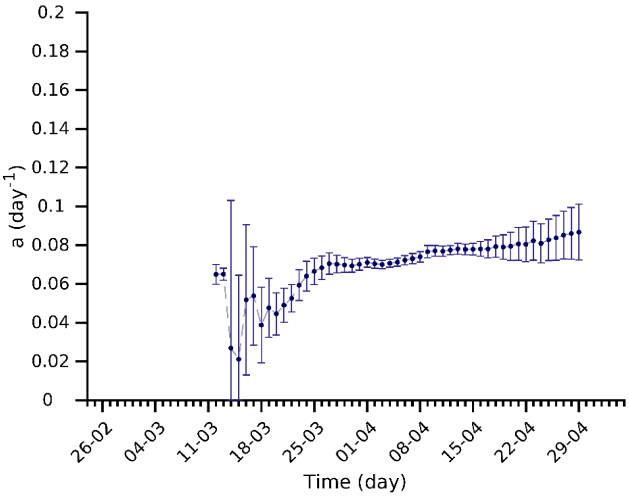


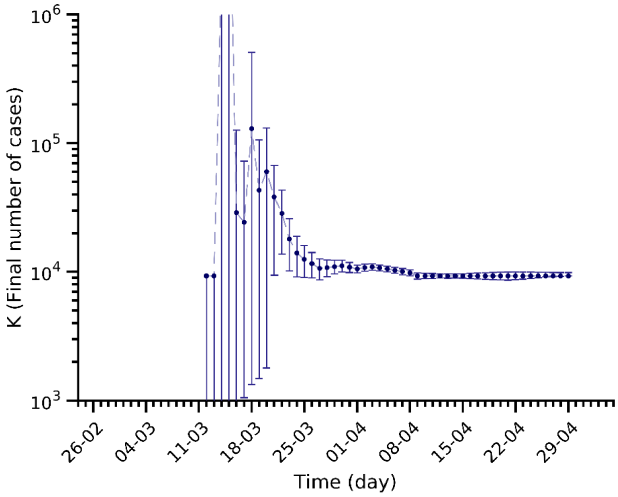


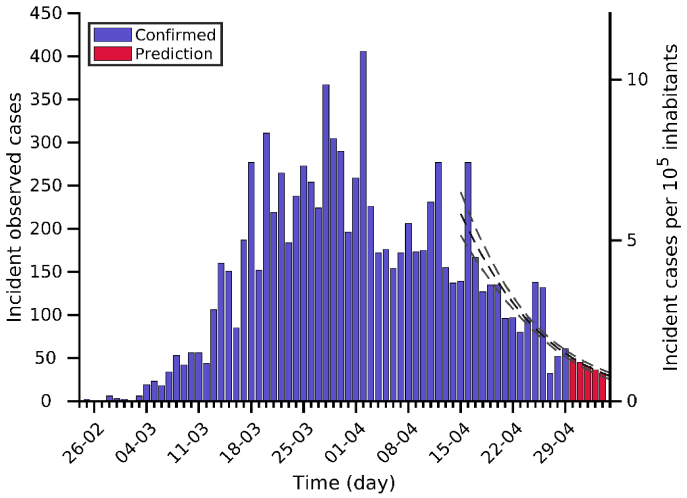
Toscana 29-04-2020. Population: 3.7M. Current cumulated incidence: 249/10⁵

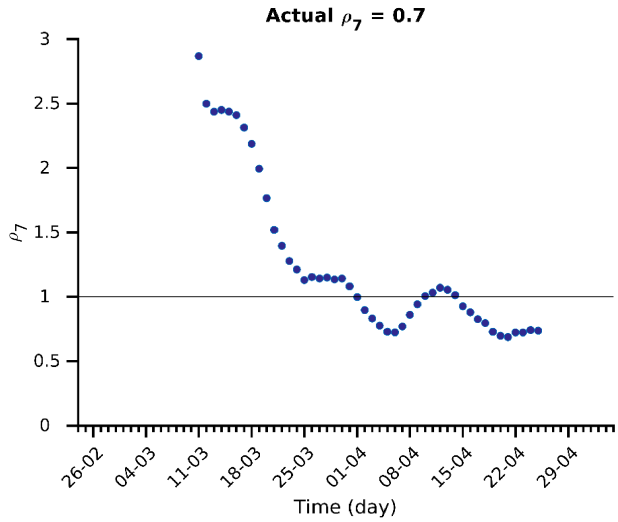


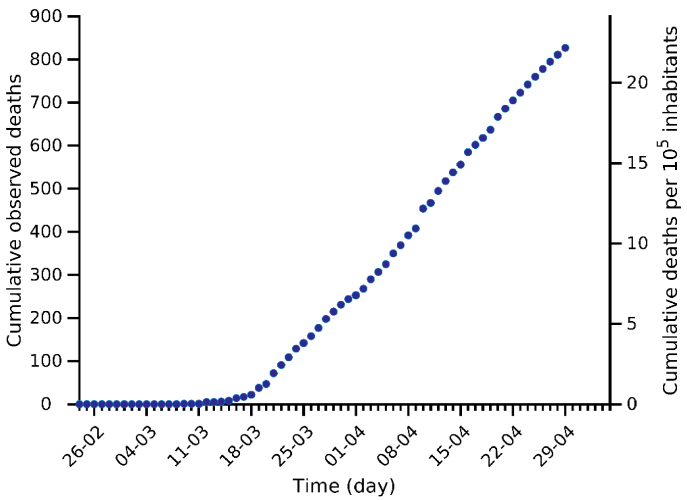


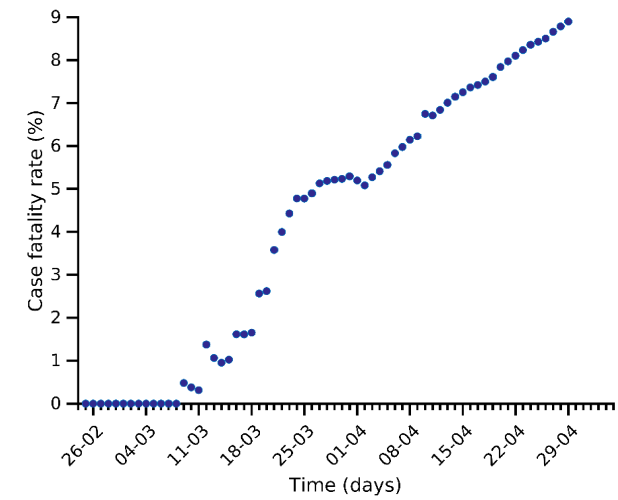




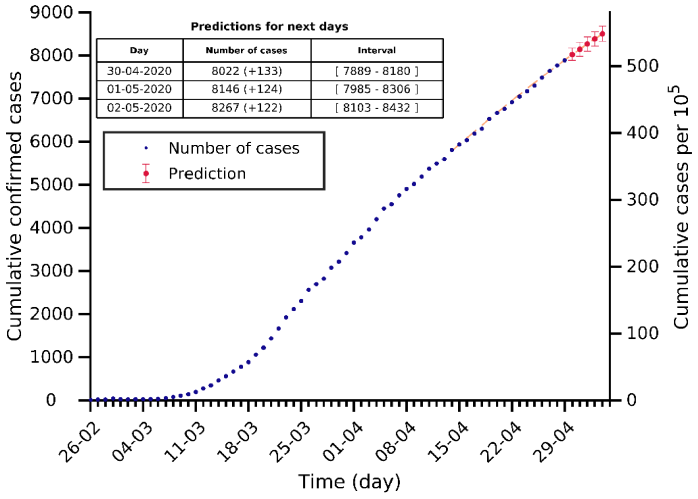


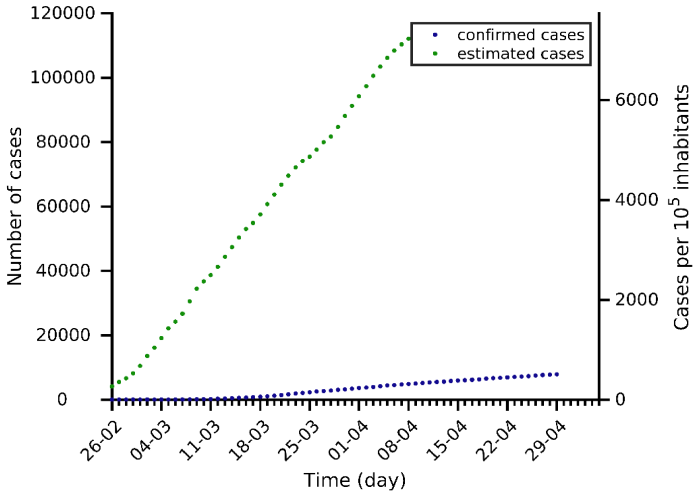


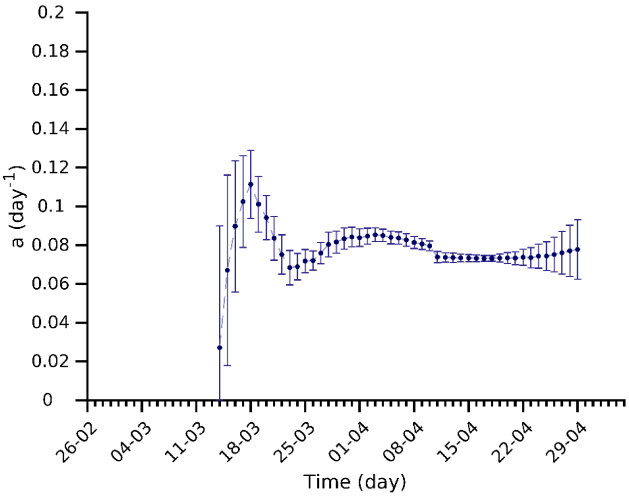


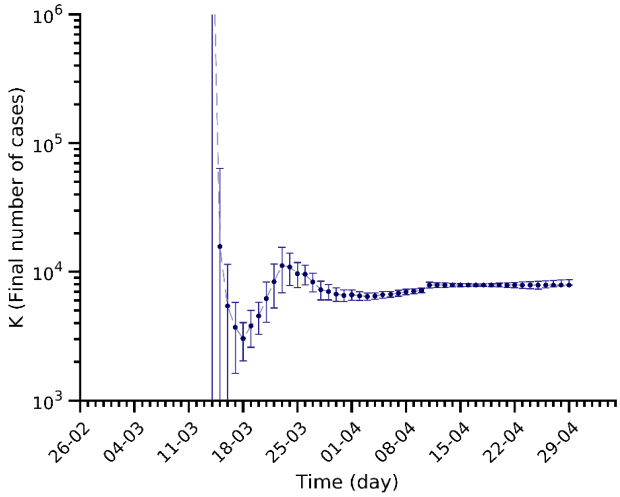


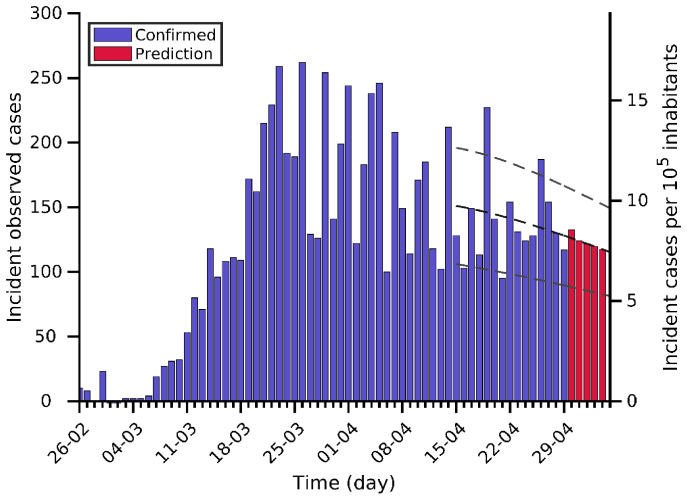
Liguria 29-04-2020. Population: 1.6M. Current cumulated incidence: 509/10^5

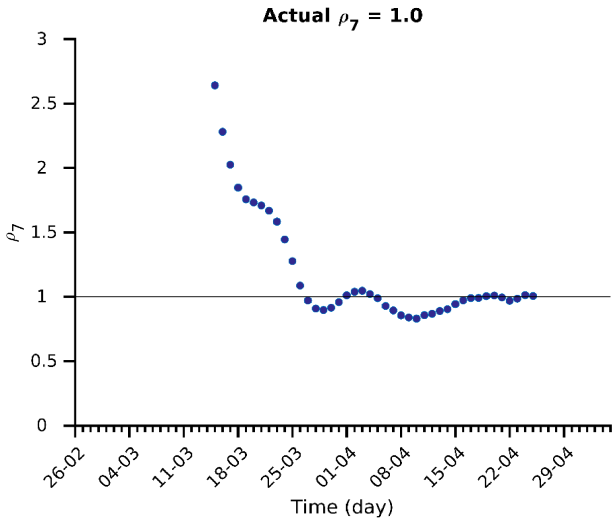


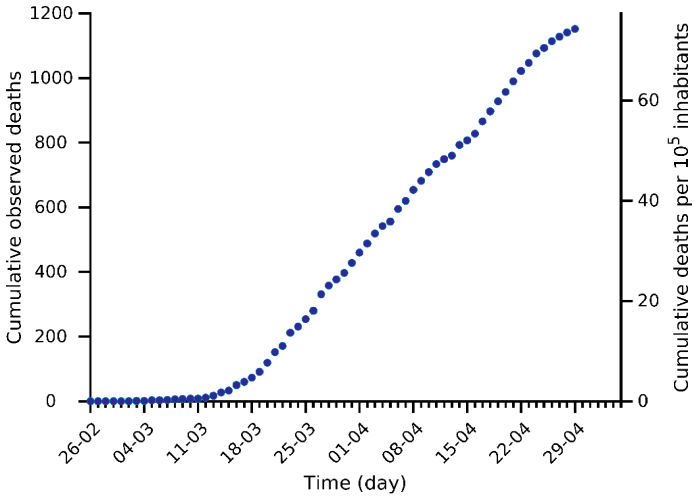


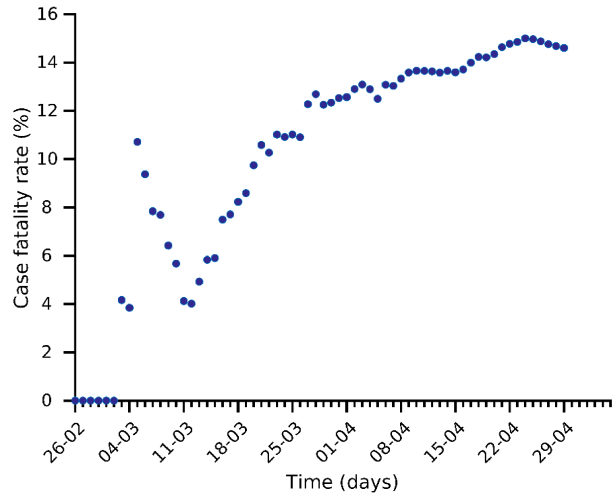




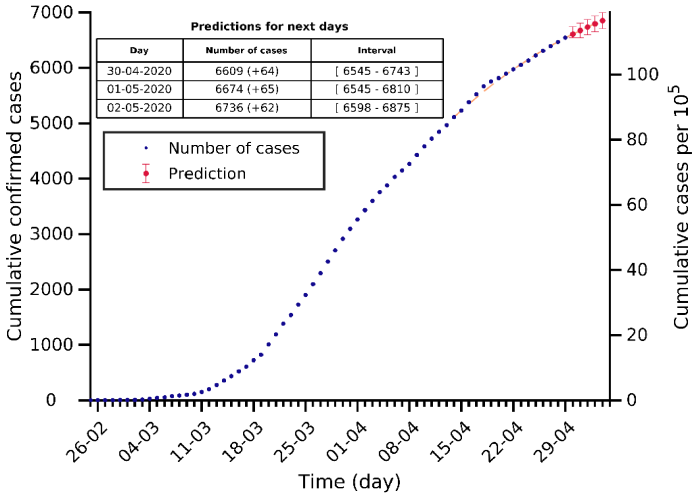


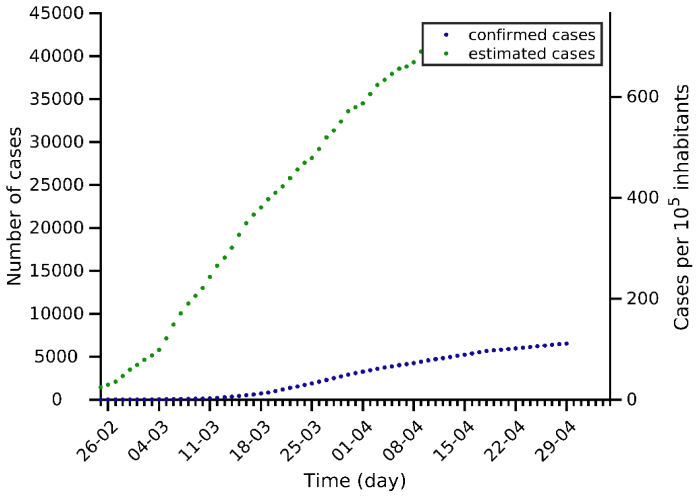


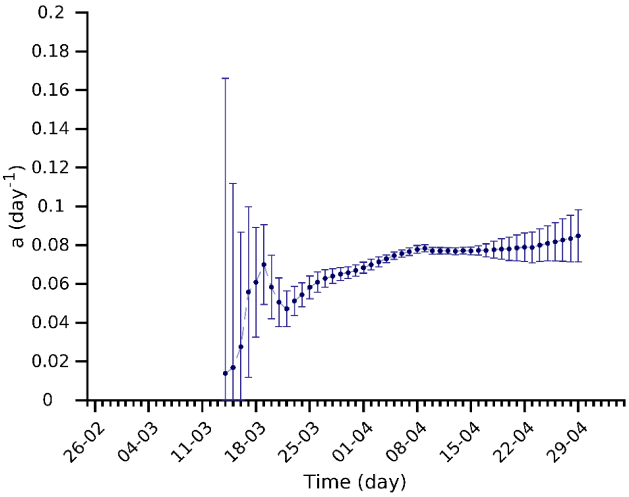


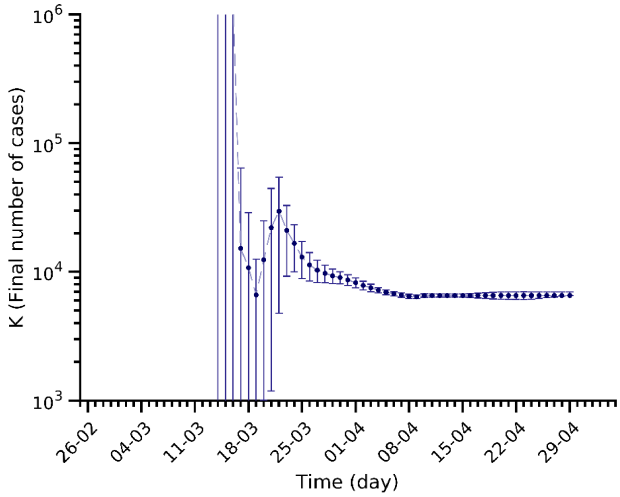


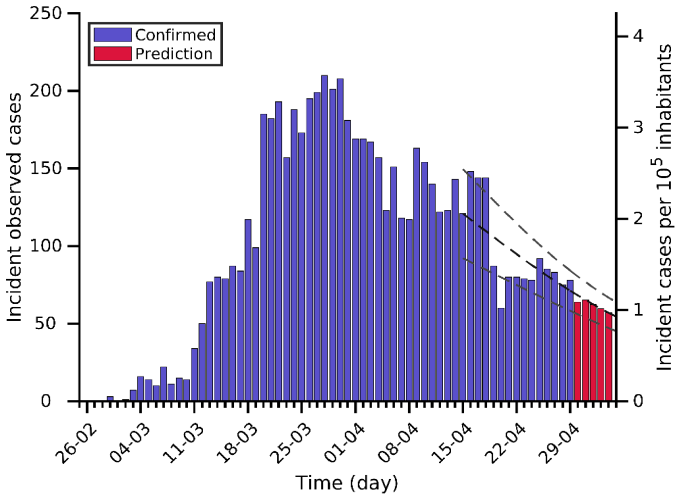
Lazio 29-04-2020. Population: 5.9M. Current cumulated incidence: 111/10⁵

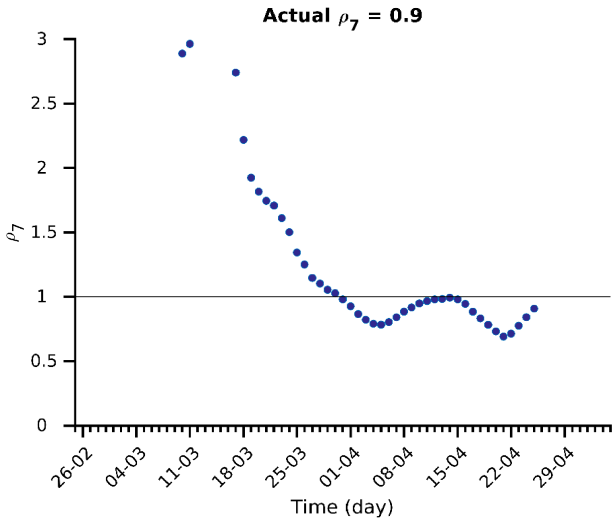


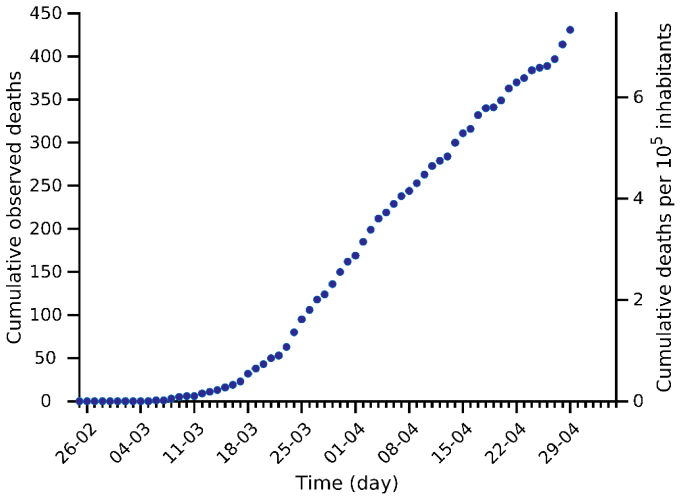


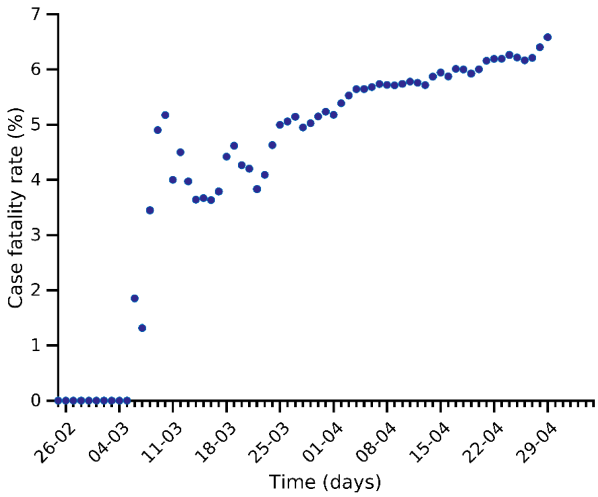




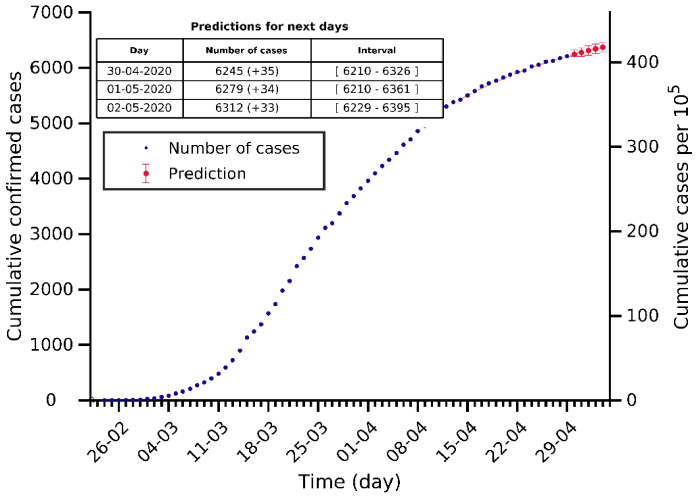


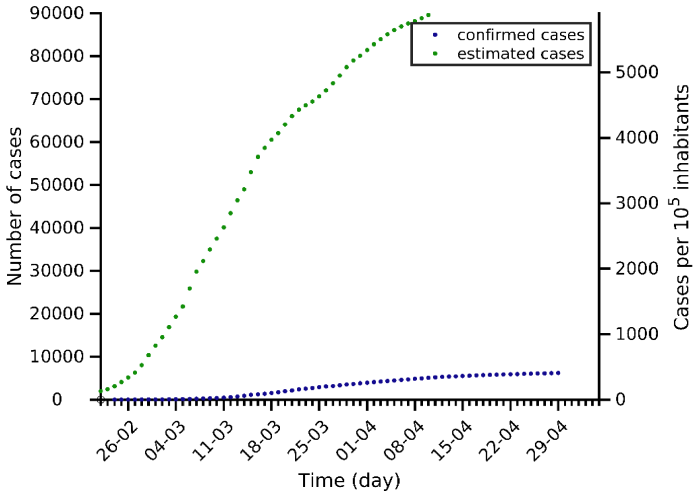


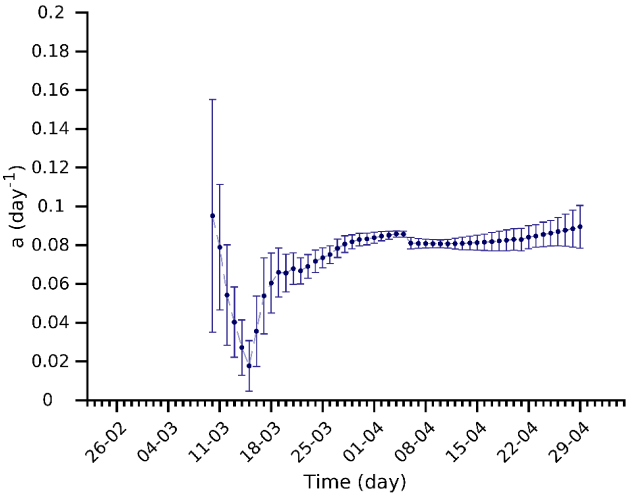


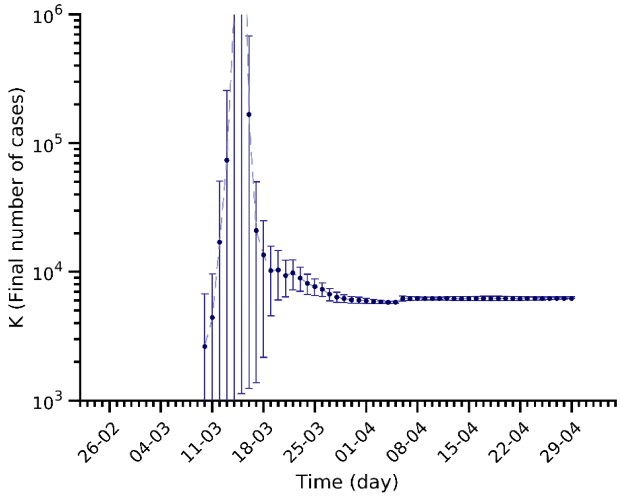


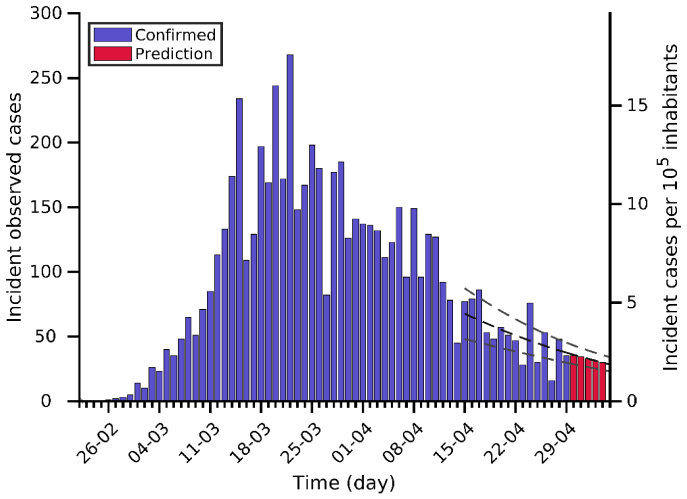
Marche 29-04-2020. Population: 1.5M. Current cumulated incidence: 407/10⁵

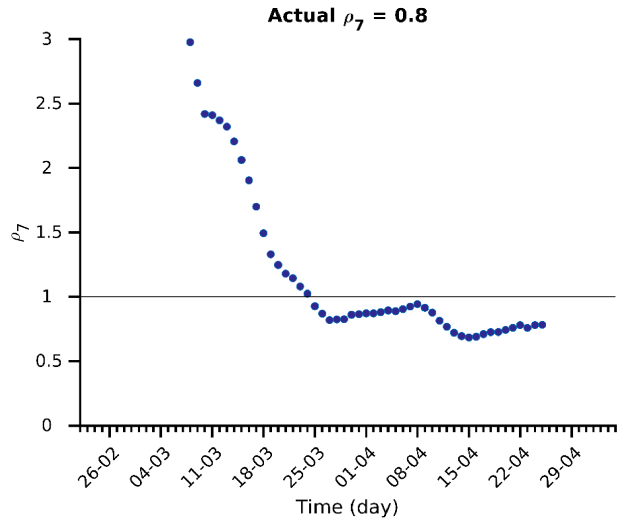


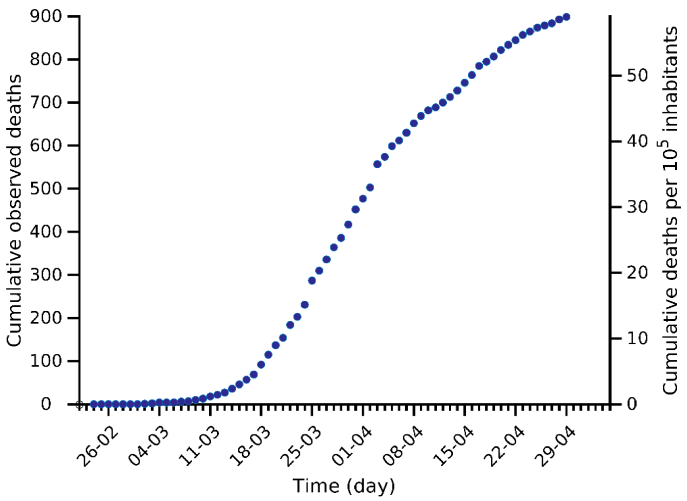


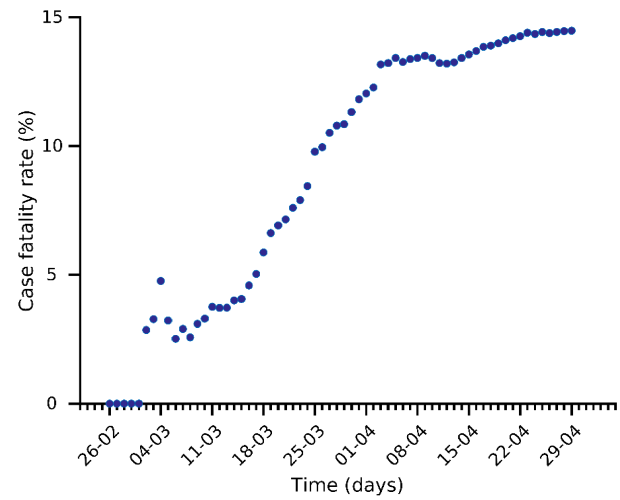




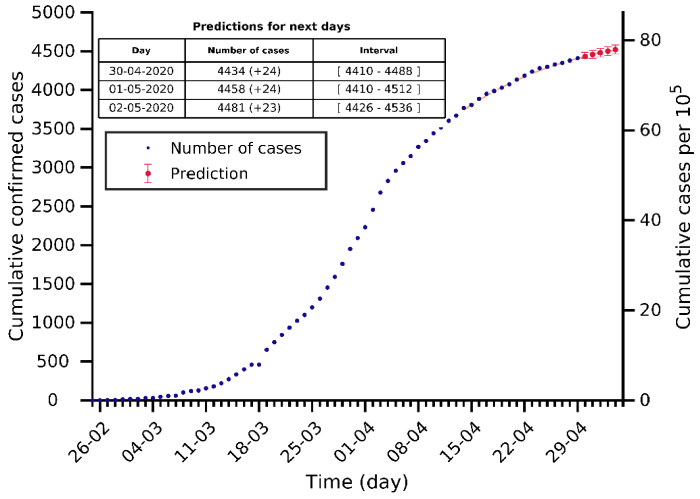


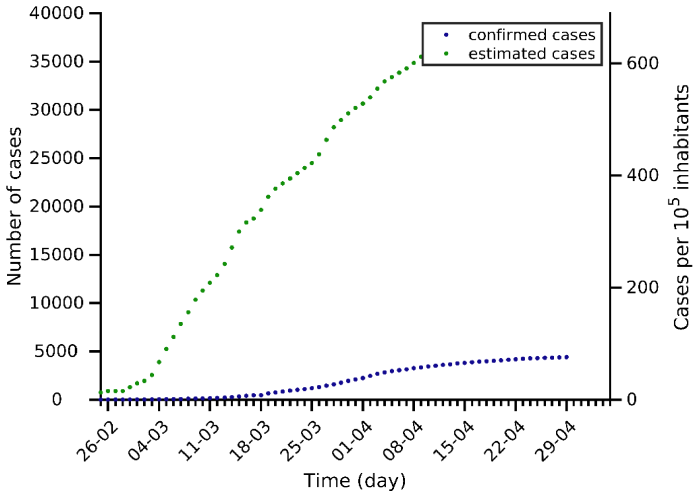


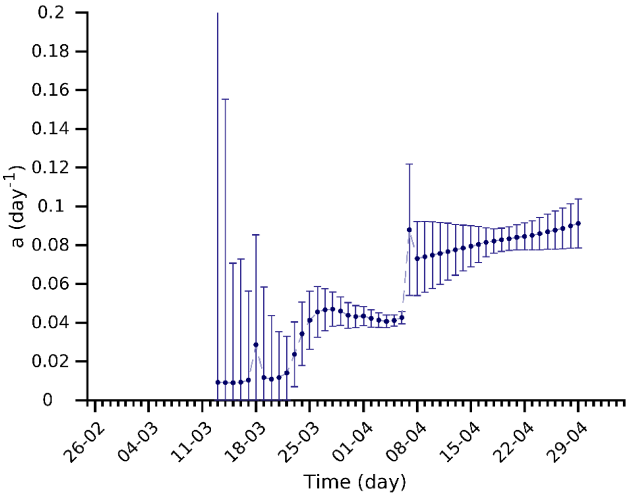


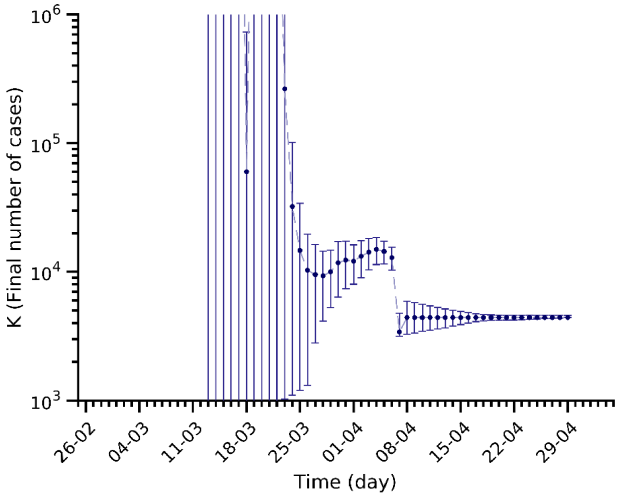


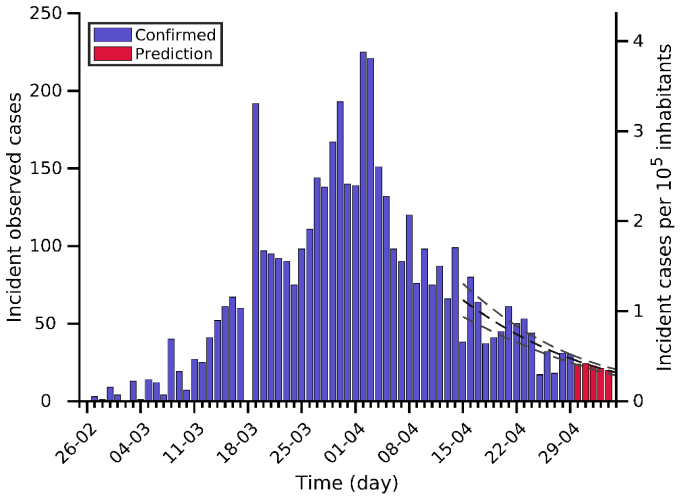
Campania 29-04-2020. Population: 5.8M. Current cumulated incidence: 76/10⁵

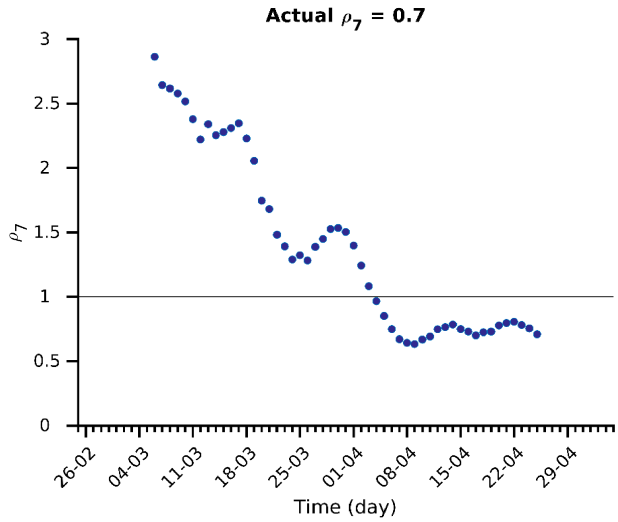


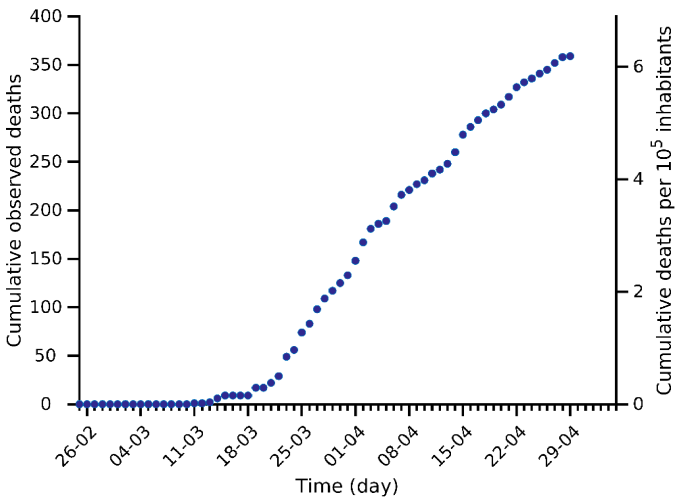


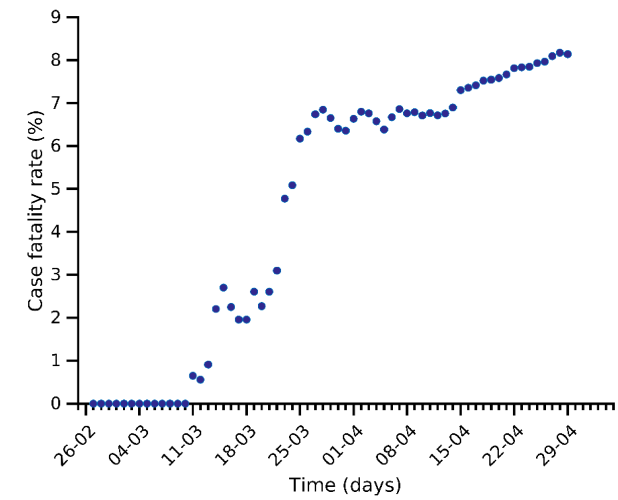




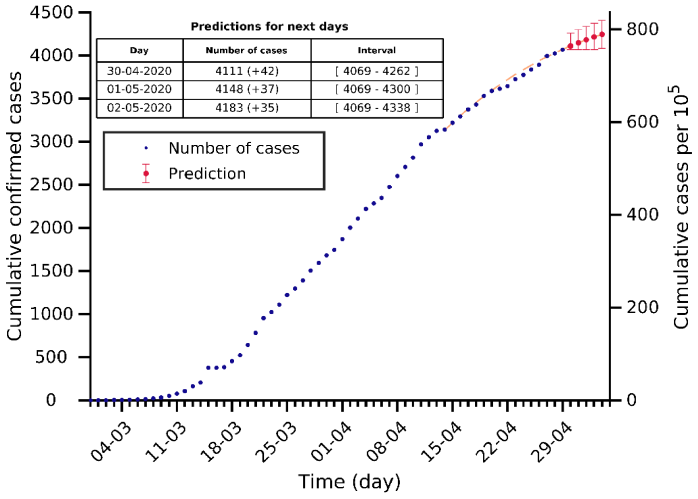


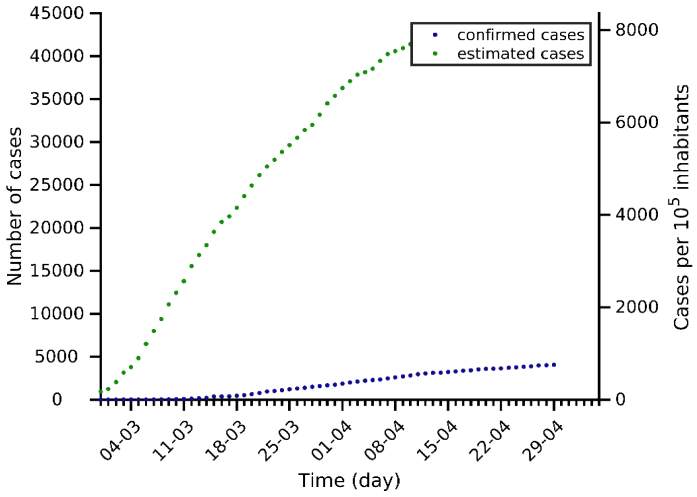


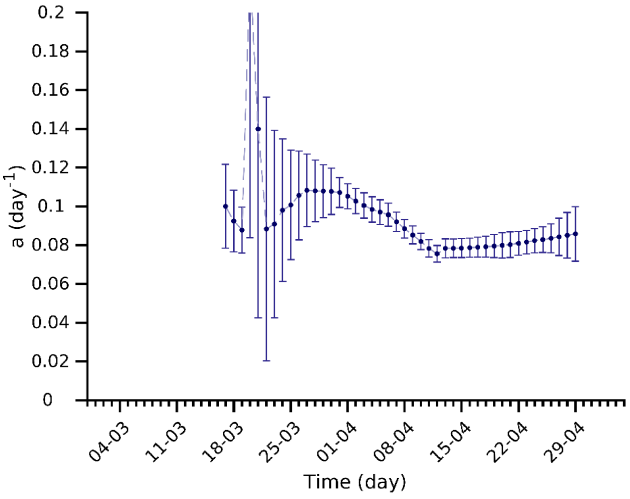


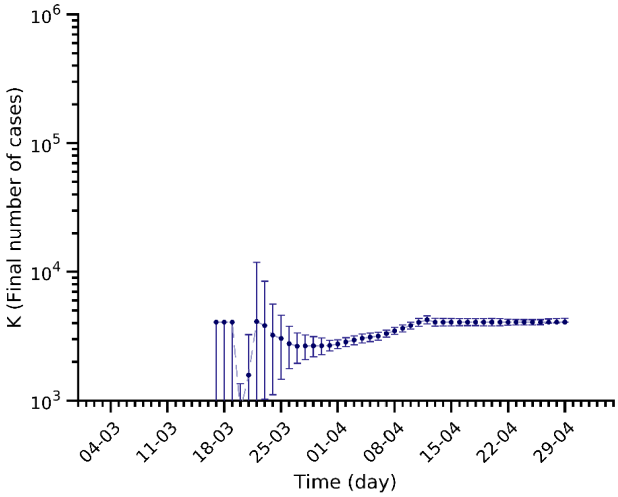


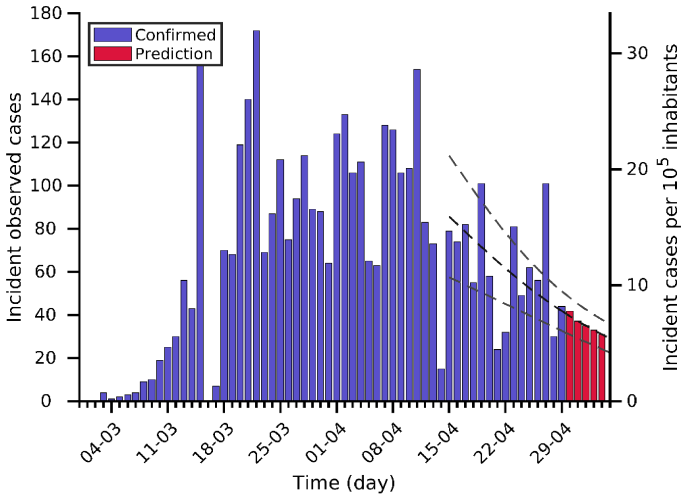
Trento 29-04-2020. Population: 0.5M. Current cumulated incidence: 756/10⁵

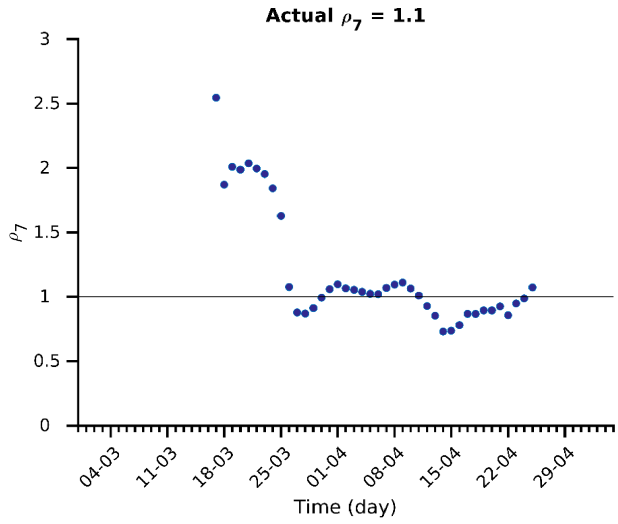


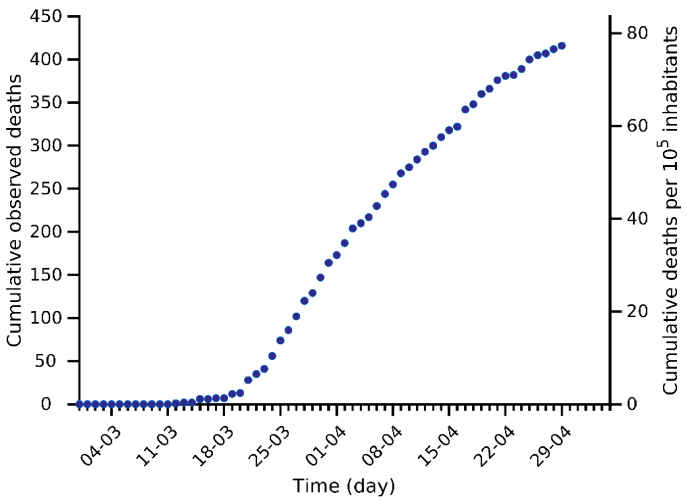


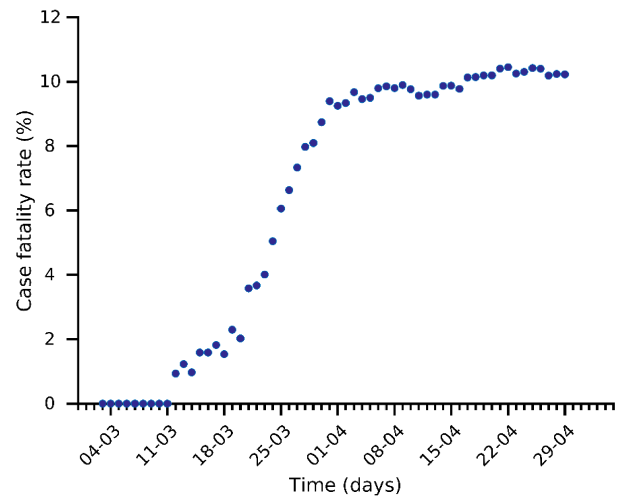




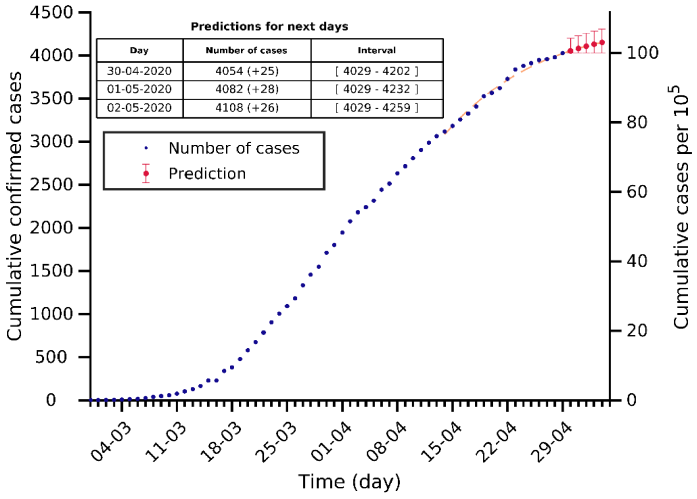


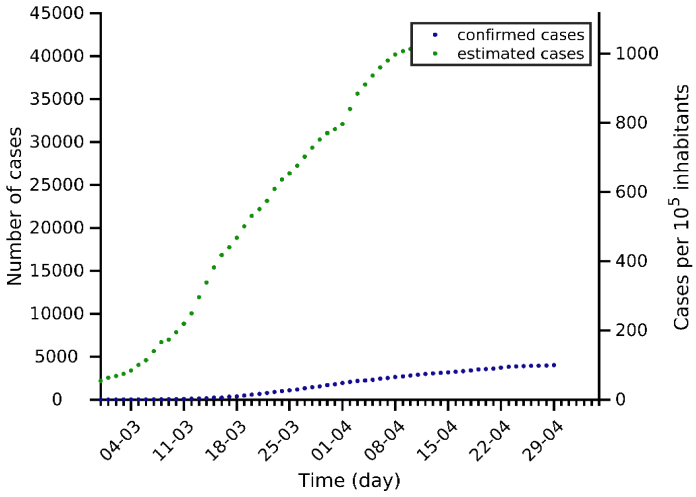


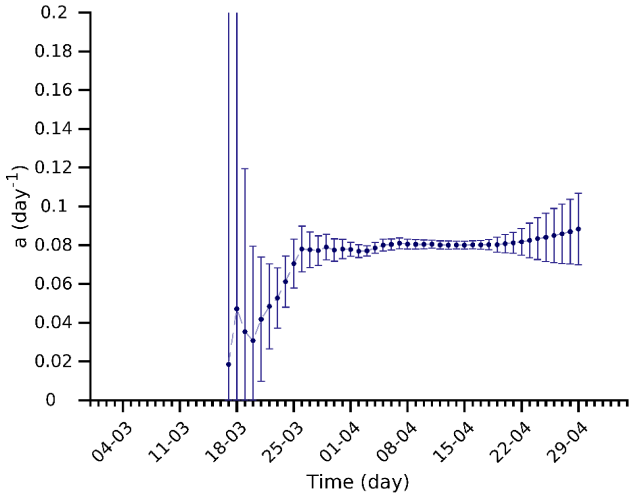


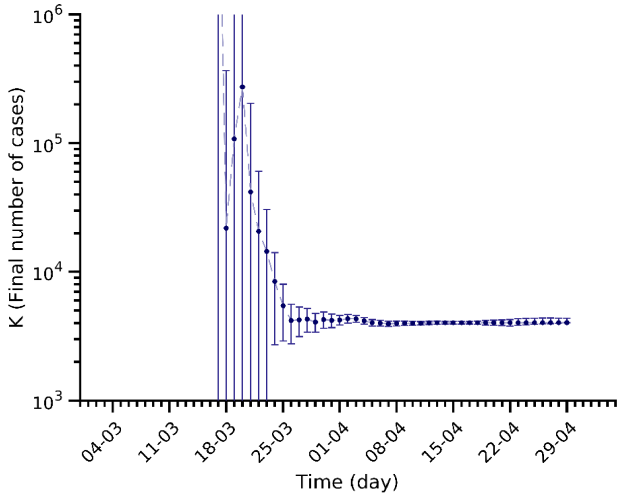


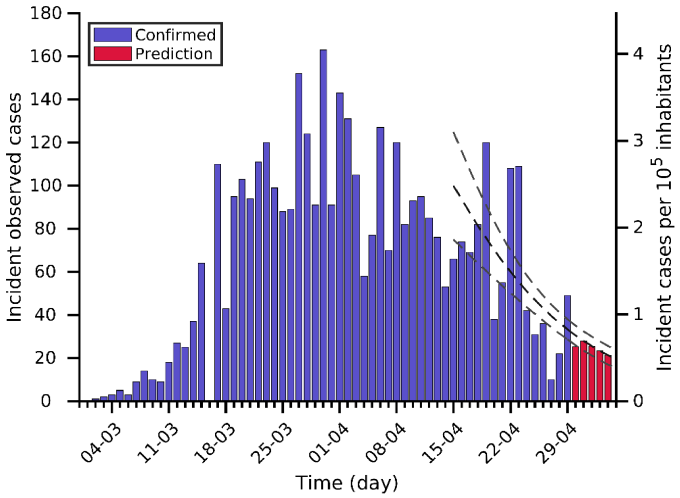
Puglia 29-04-2020. Population: 4.0M. Current cumulated incidence: 100/10^5

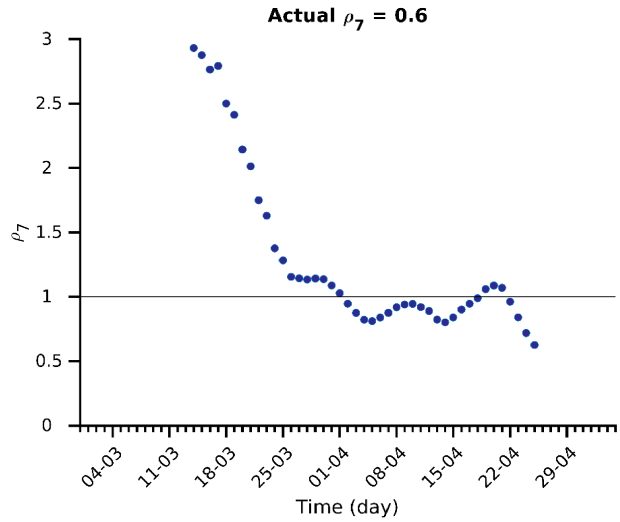


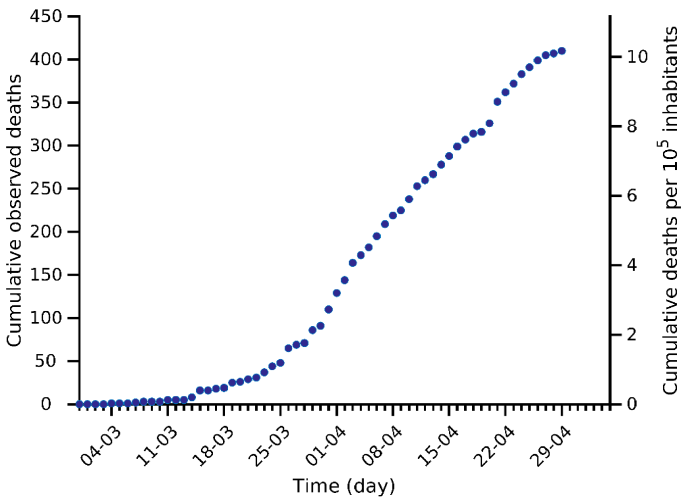


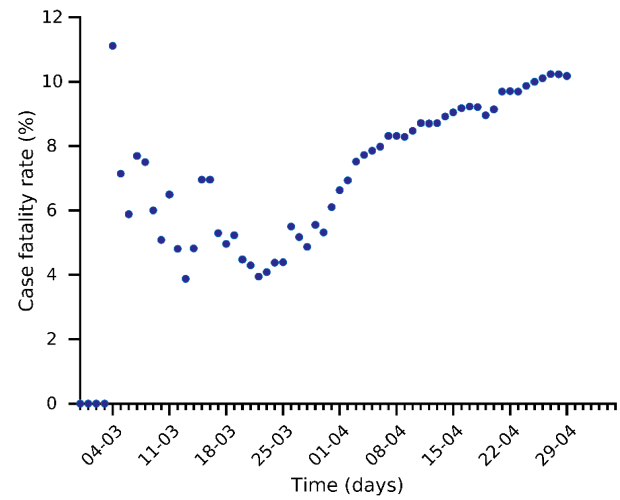




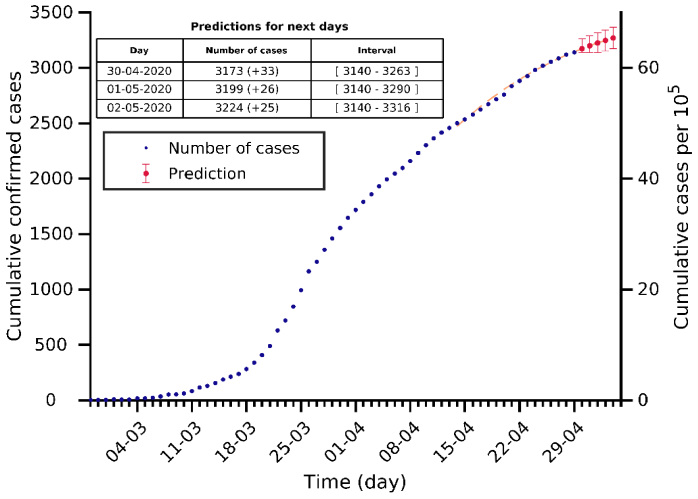


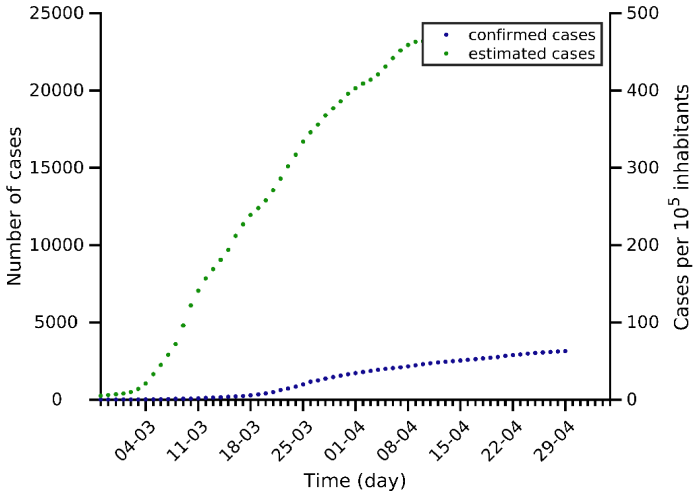


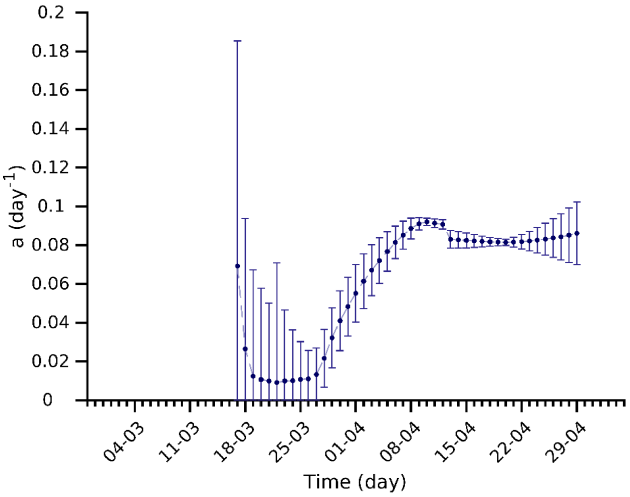


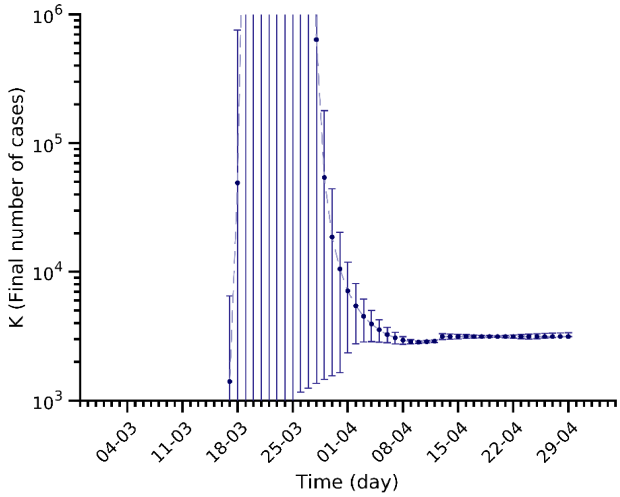


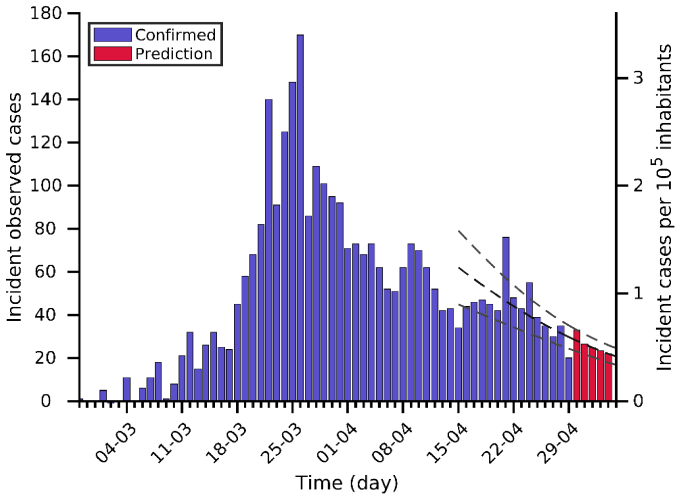
Sicilia 29-04-2020. Population: 5.0M. Current cumulated incidence: 63/10⁵

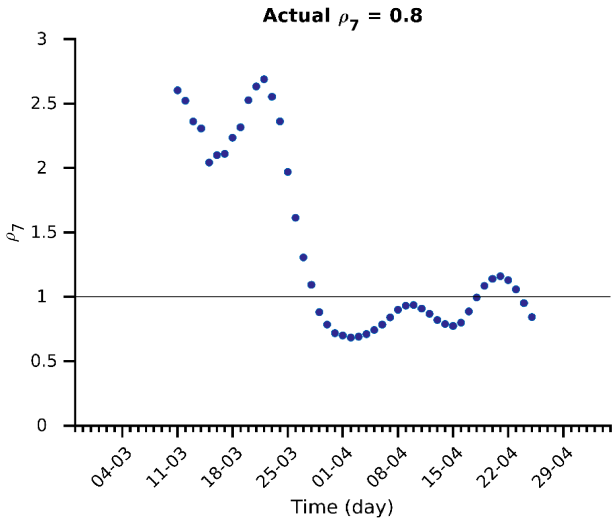


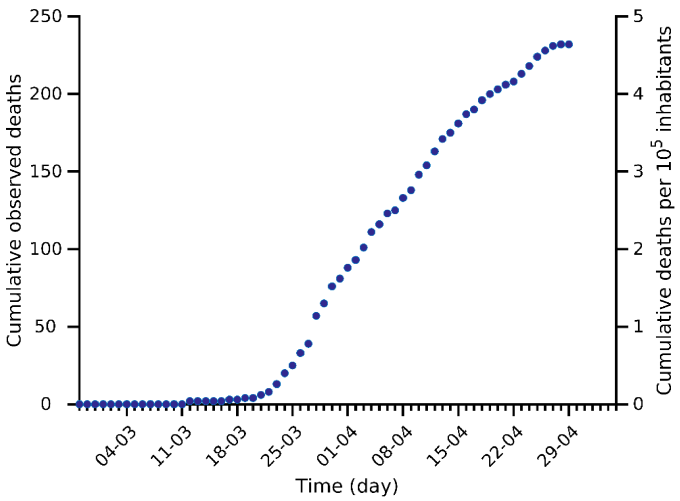


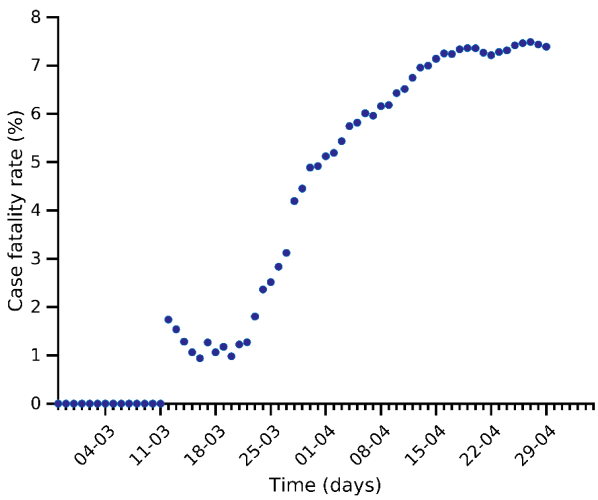




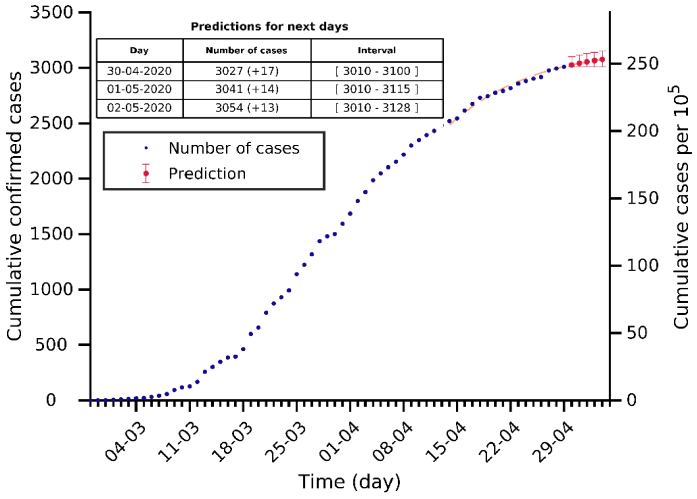


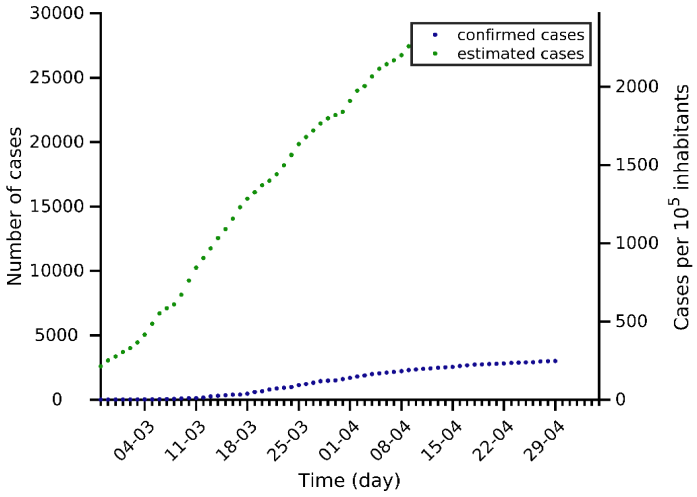


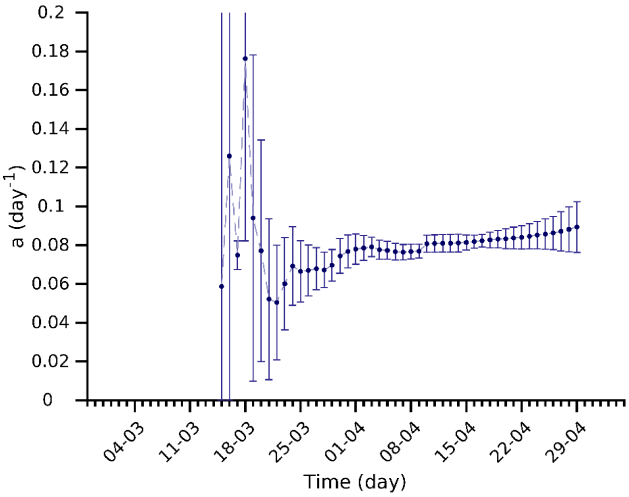


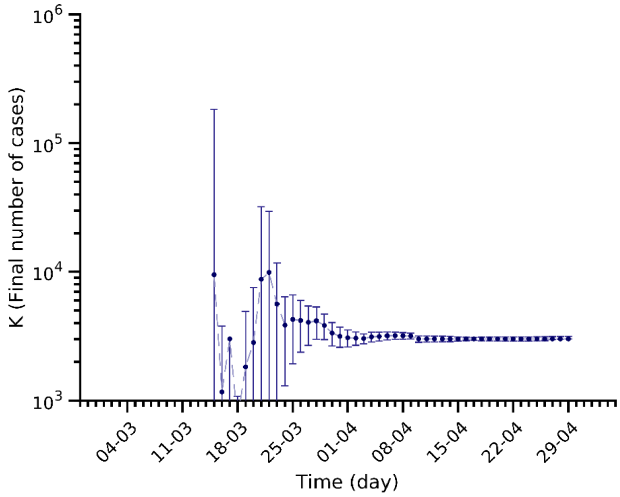


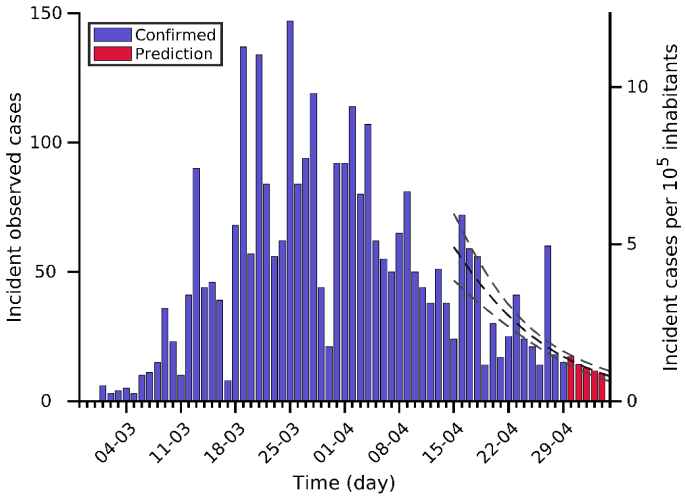
Friuli Venezia Giulia 29-04-2020. Population: 1.2M. Current cumulated incidence: 2

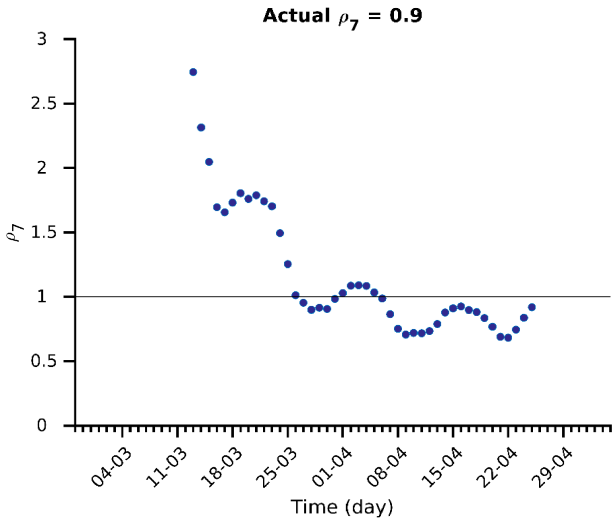


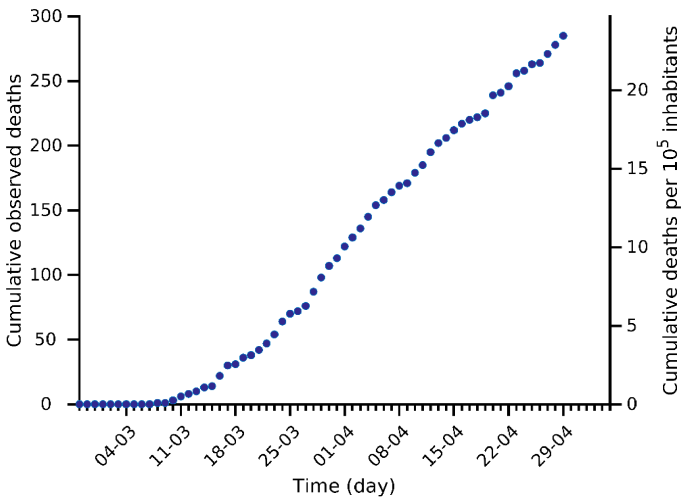


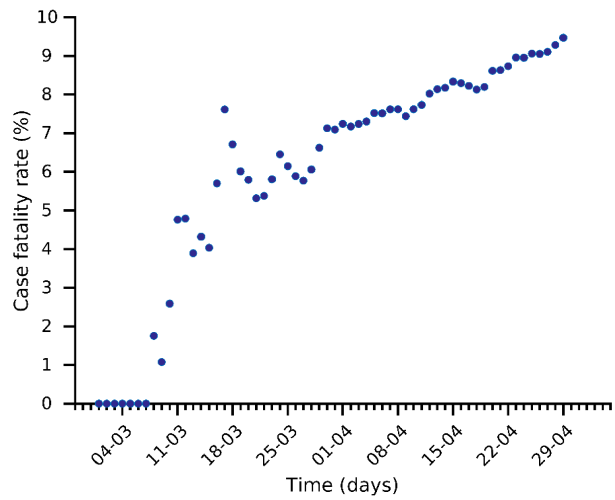




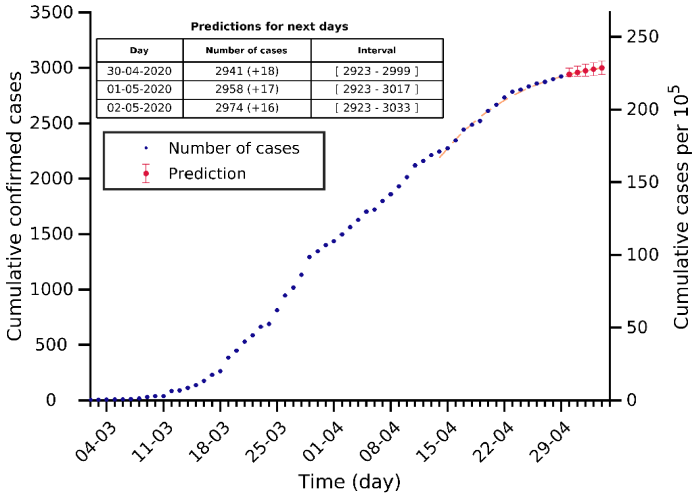


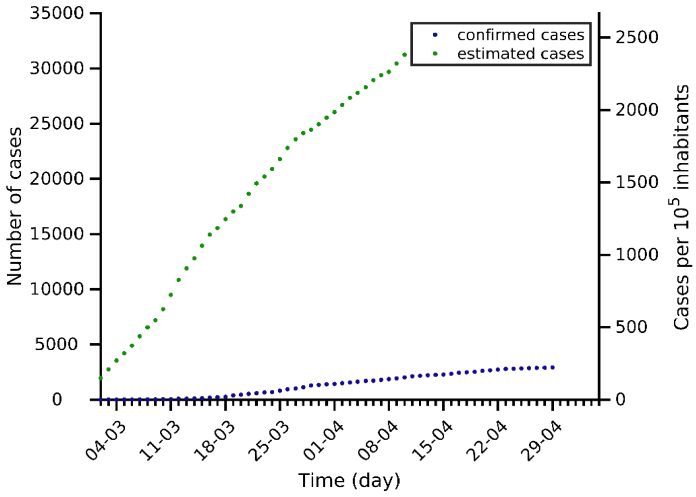


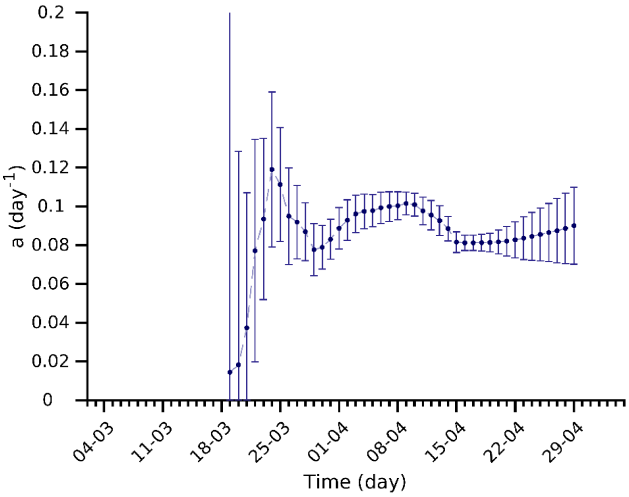


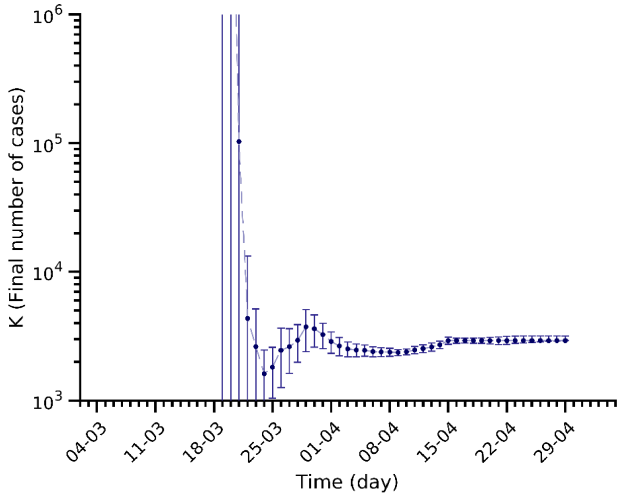


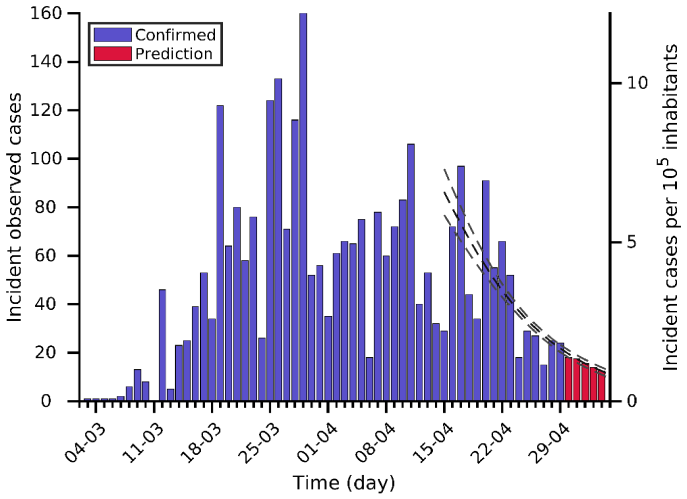
Abruzzo 29-04-2020. Population: 1.3M. Current cumulated incidence: $223/10^5$

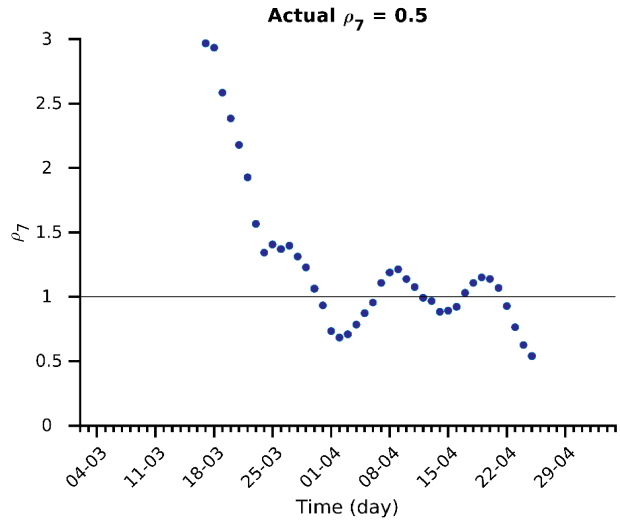


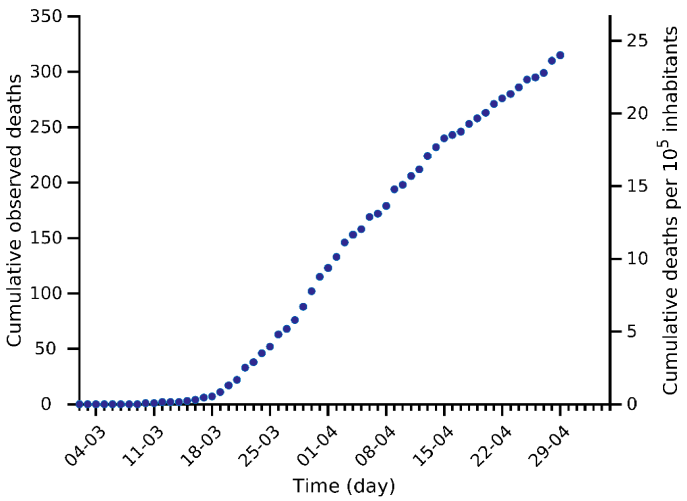


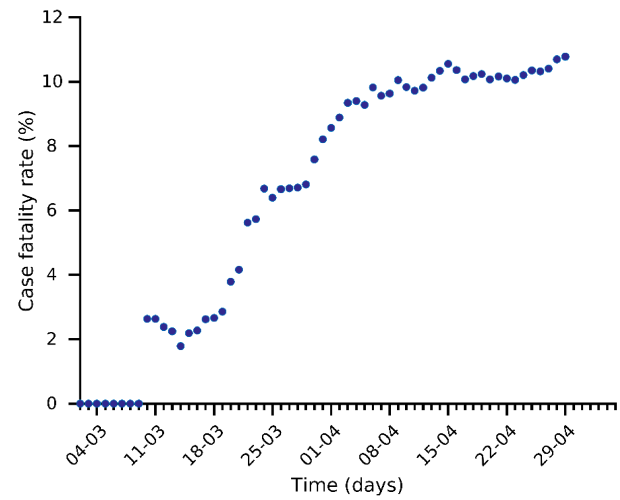




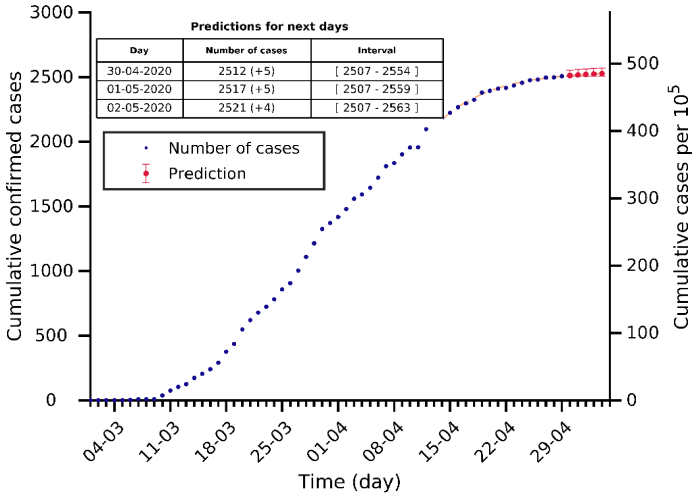


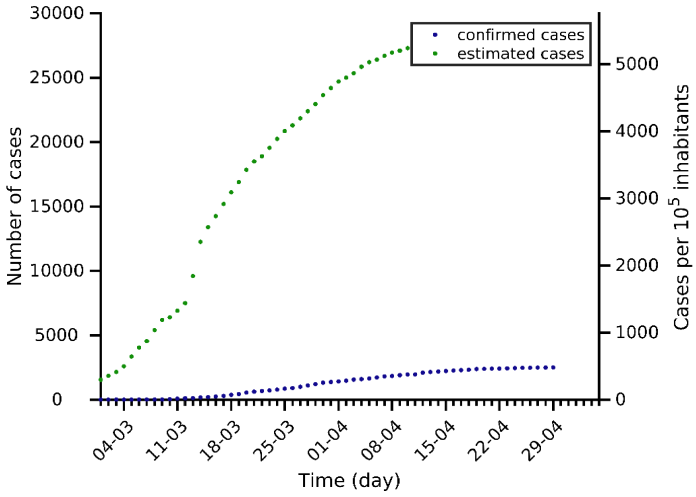


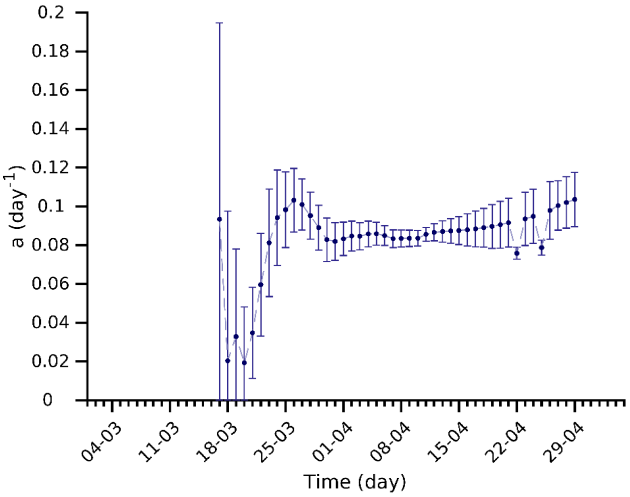


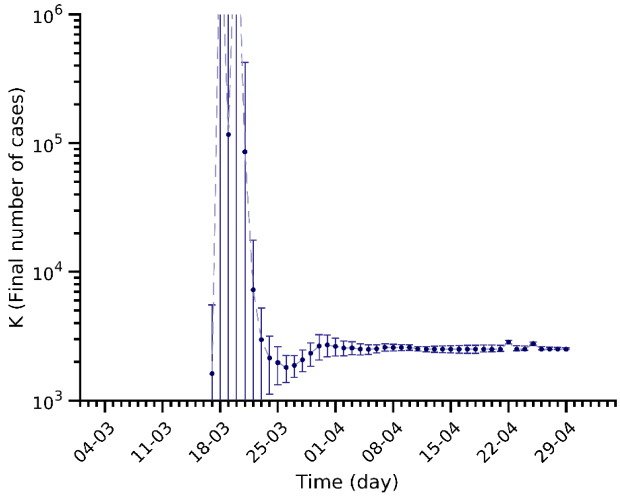


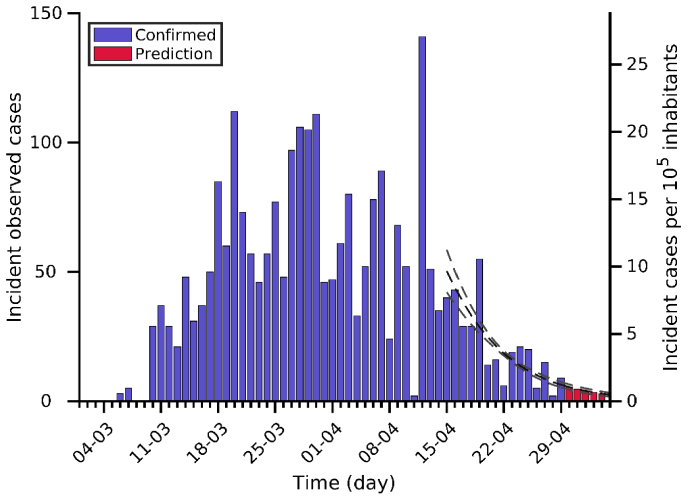
Bolzano 29-04-2020. Population: 0.5M. Current cumulated incidence: 481/10⁵

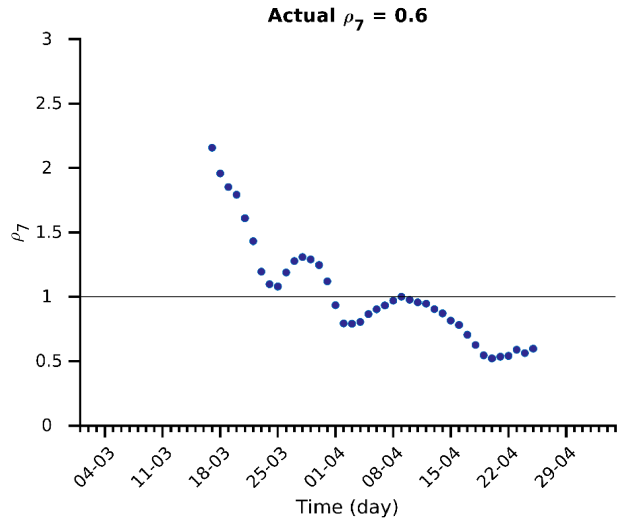


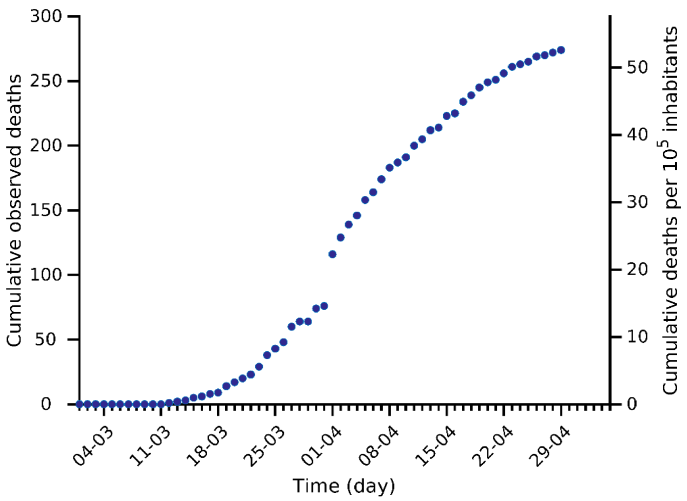


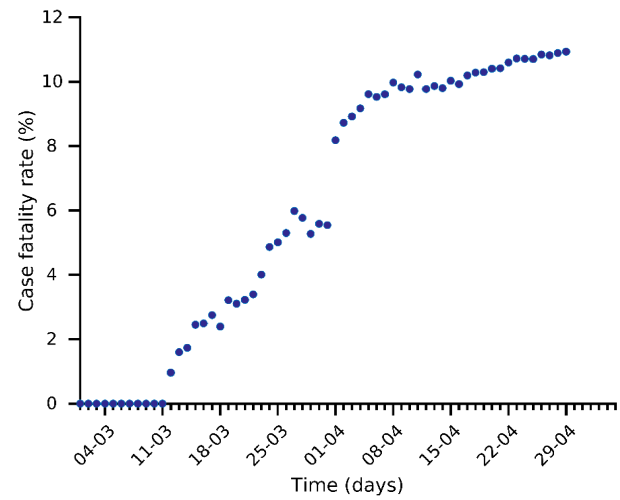




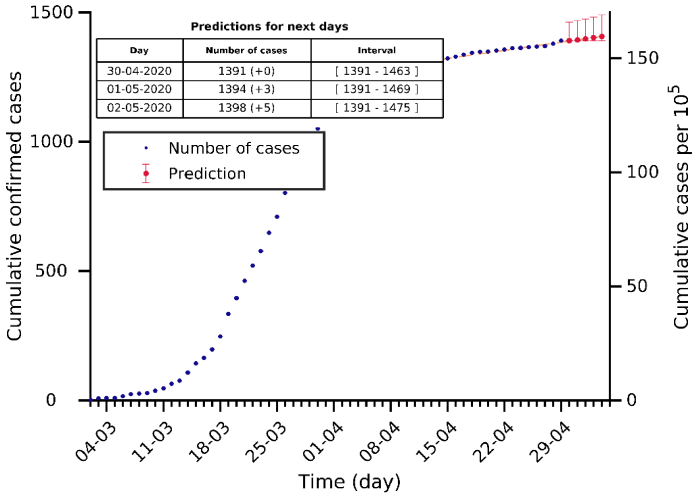


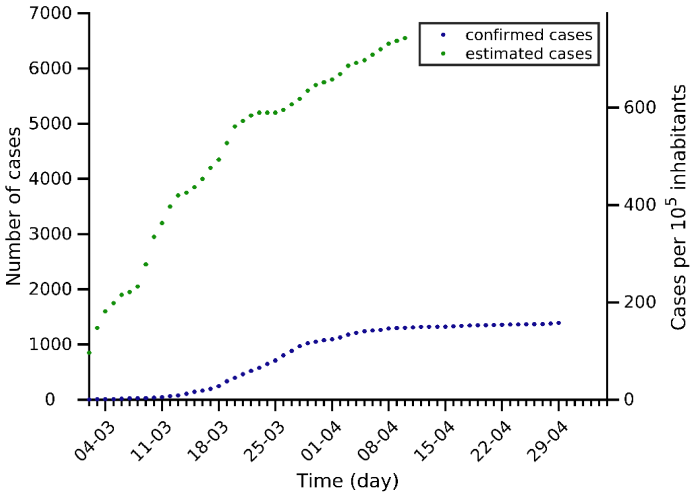


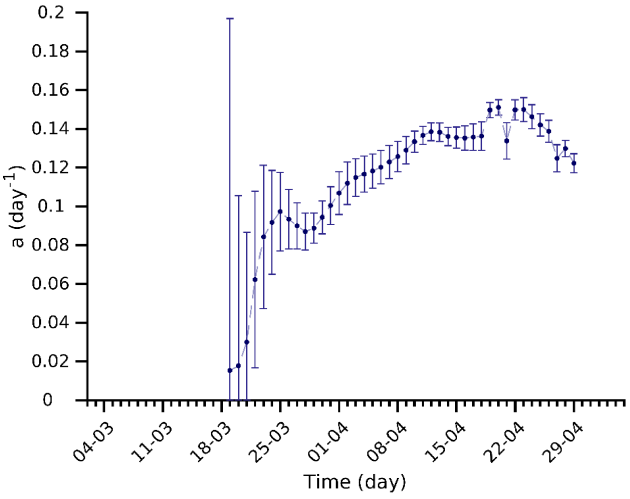


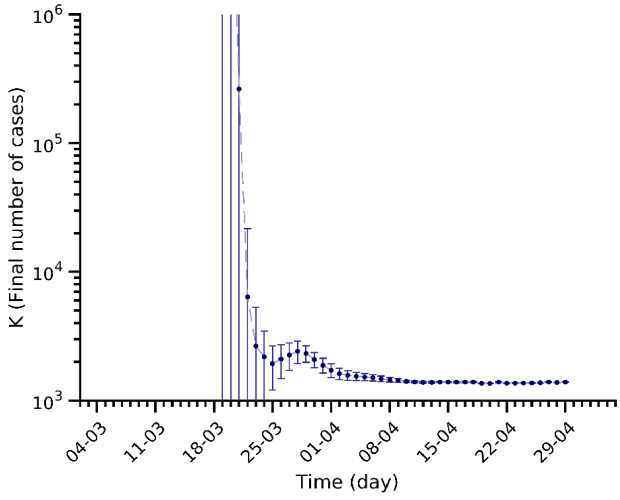


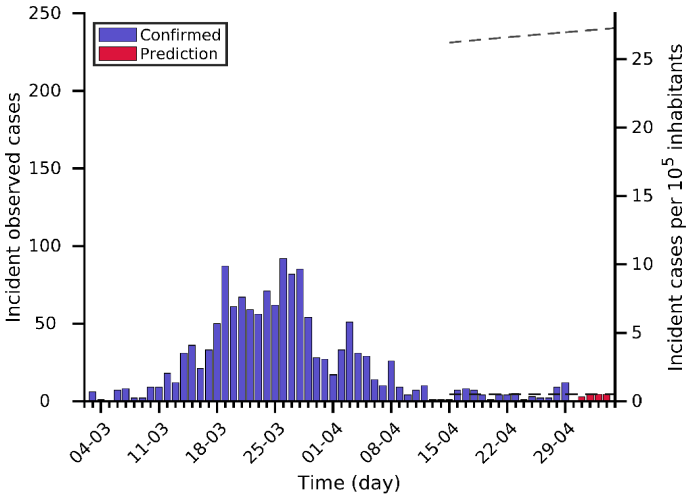
Umbria 29-04-2020. Population: 0.9M. Current cumulated incidence: $158/10^5$

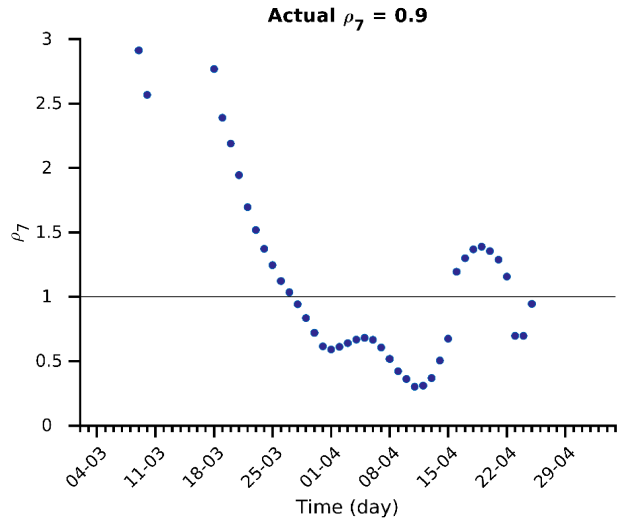


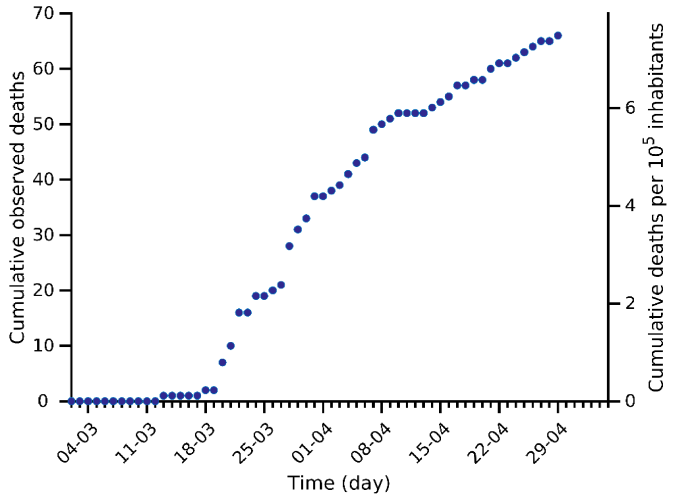


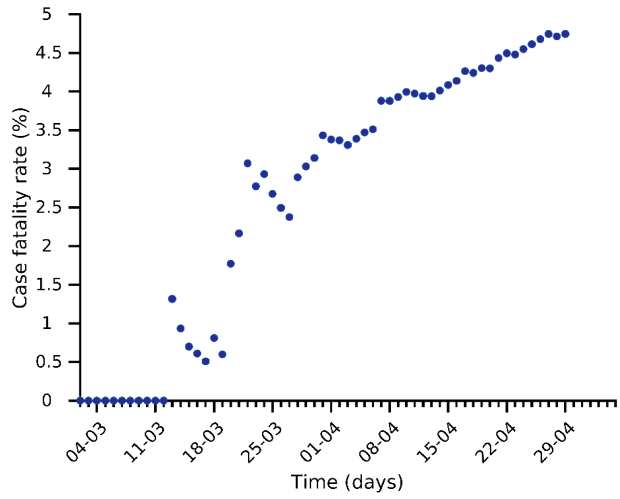




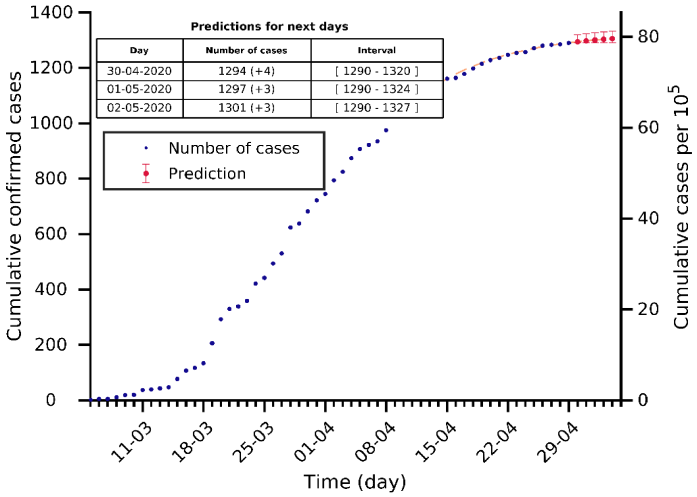


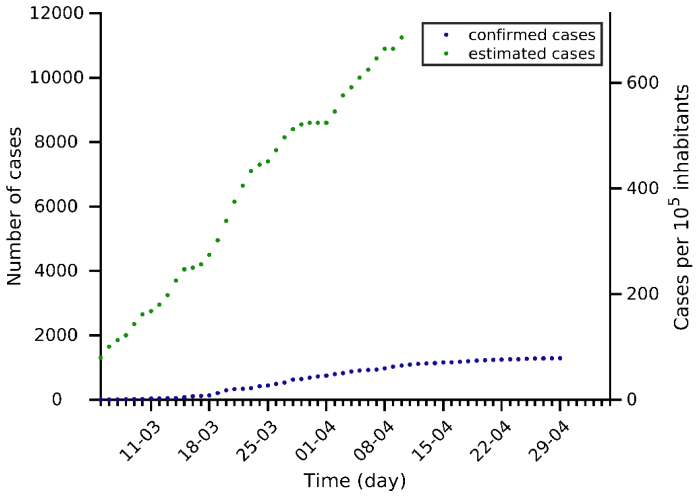


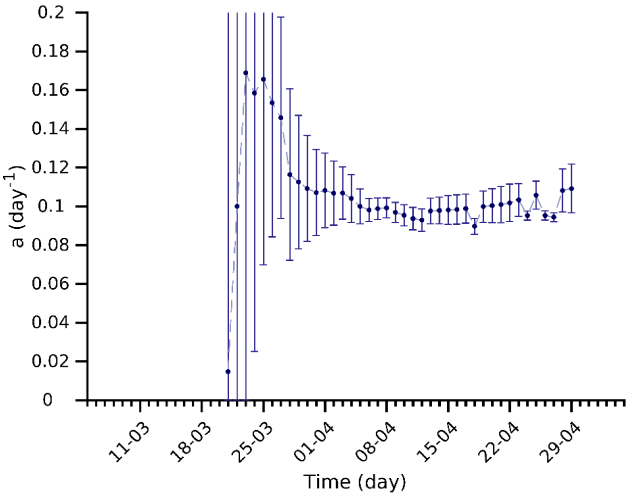


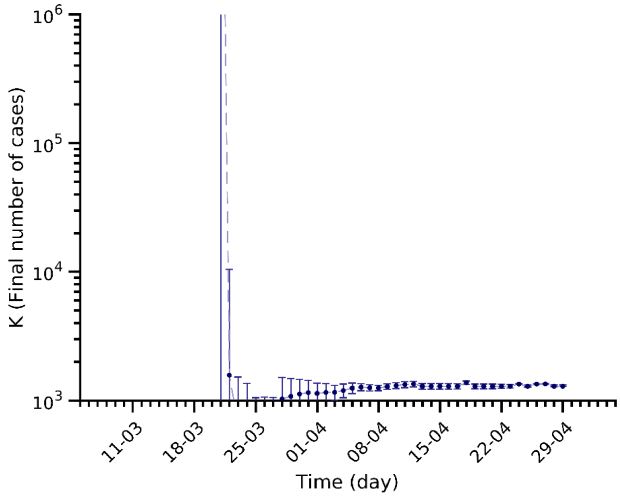


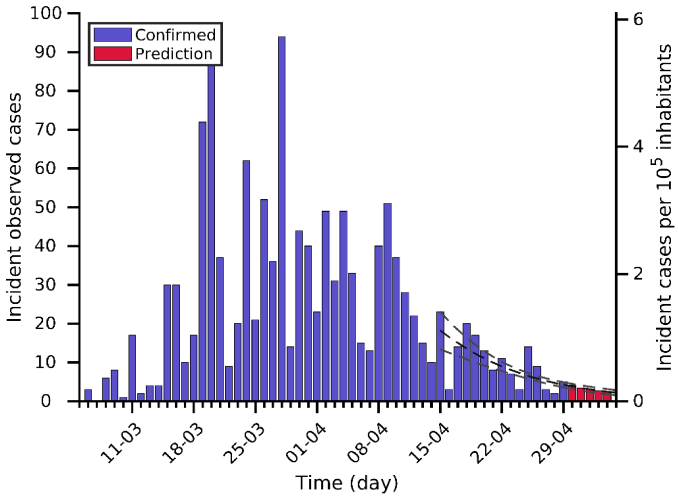
Sardegna 29-04-2020. Population: 1.6M. Current cumulated incidence: 79/10^5

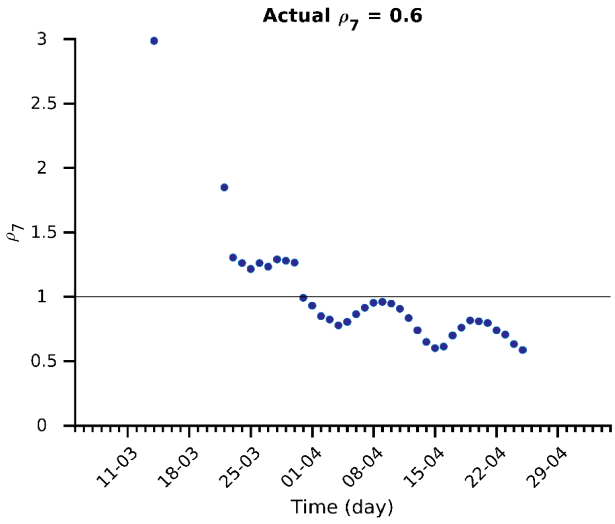


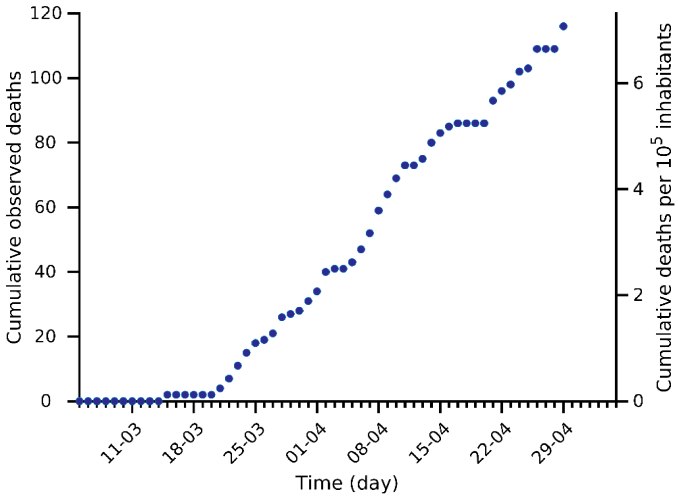


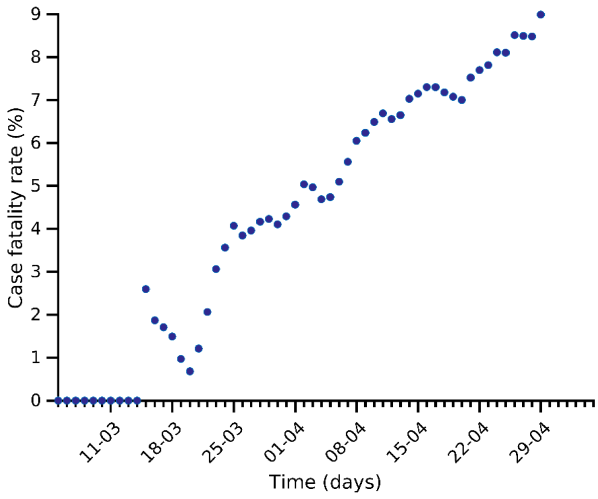




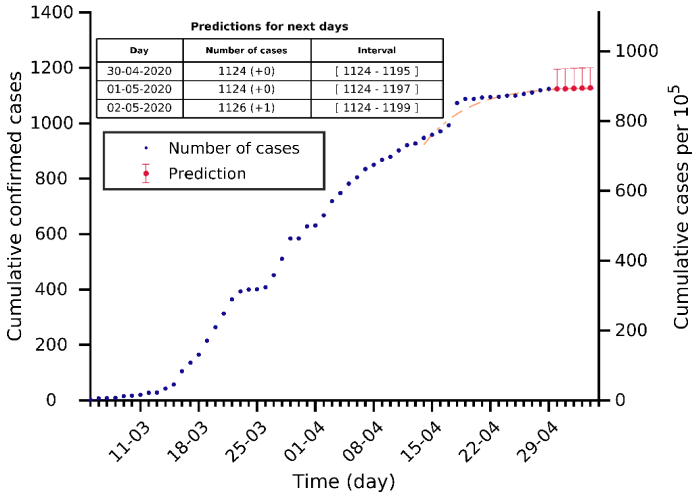


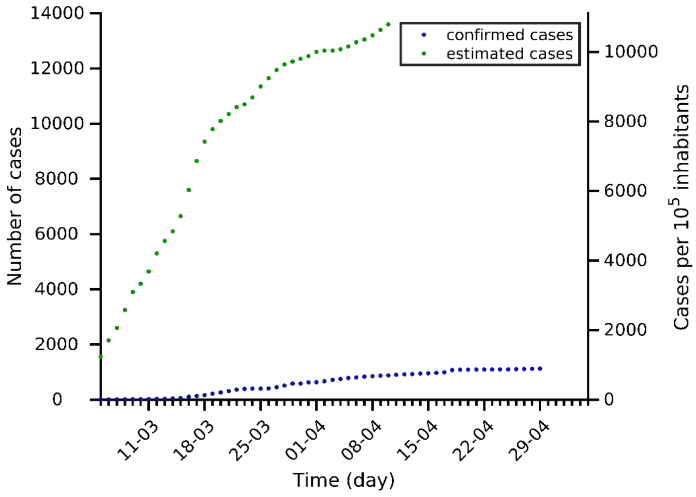


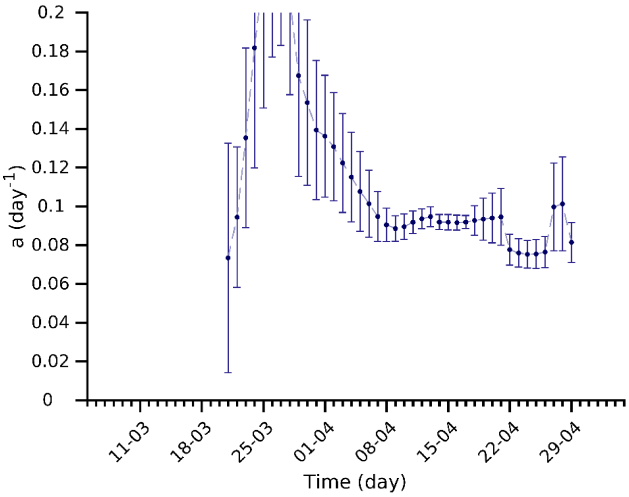


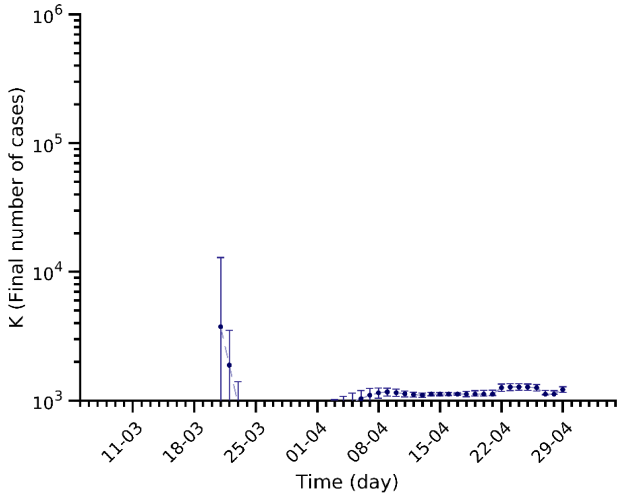


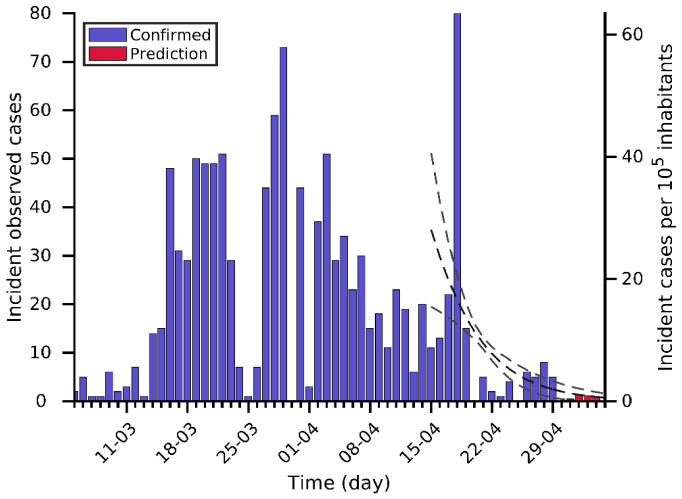
Valle dAosta 29-04-2020. Population: 0.1M. Current cumulated incidence: 892/10^5

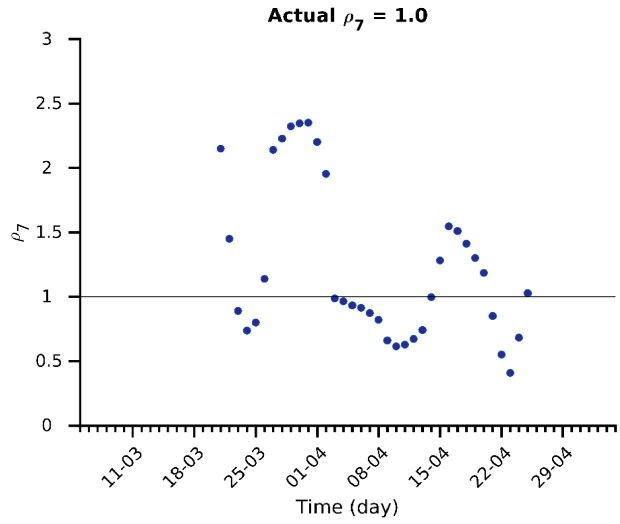


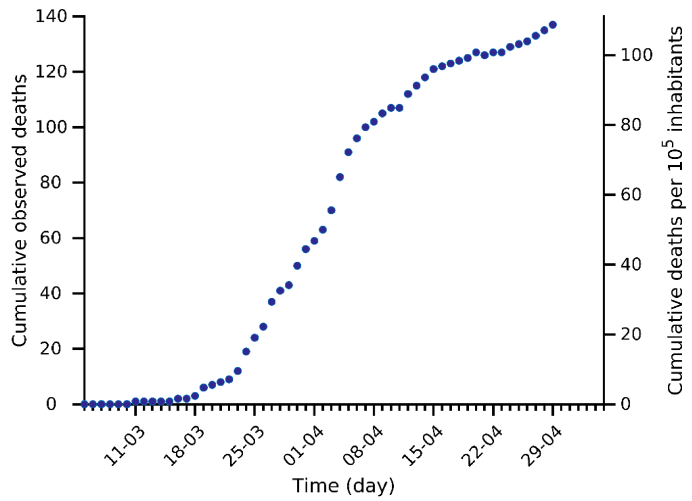


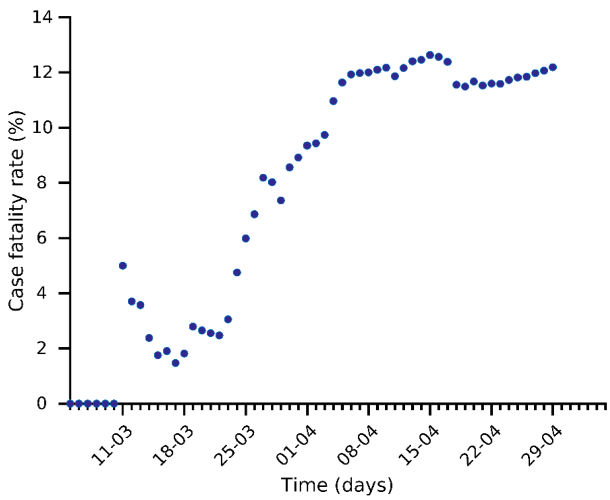




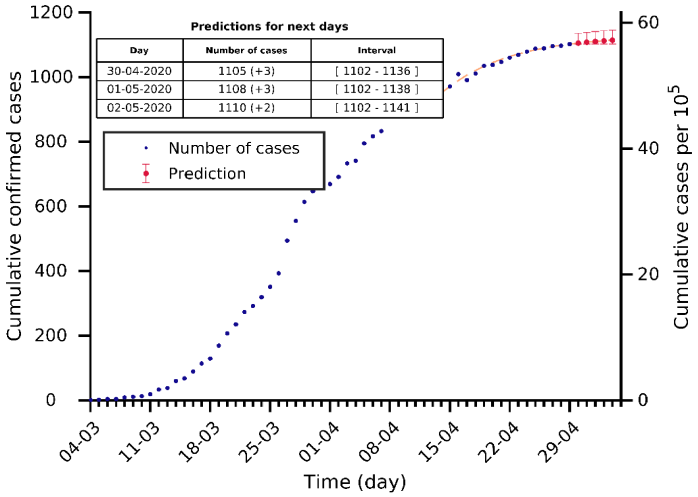


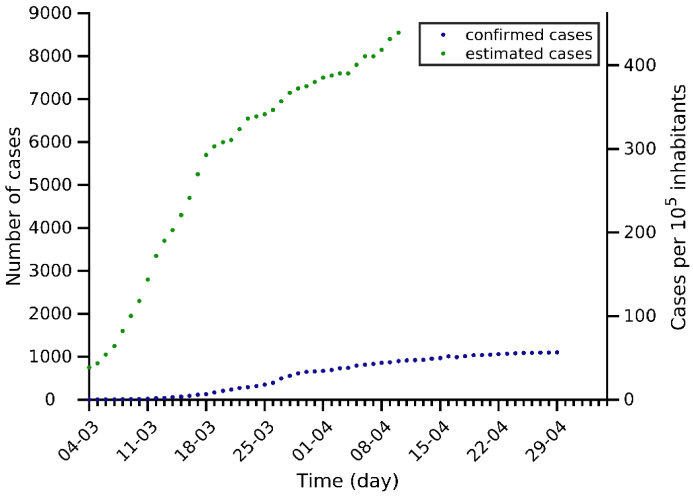


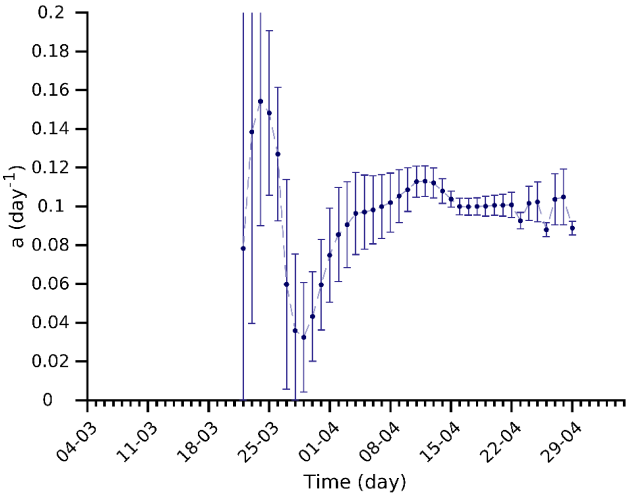


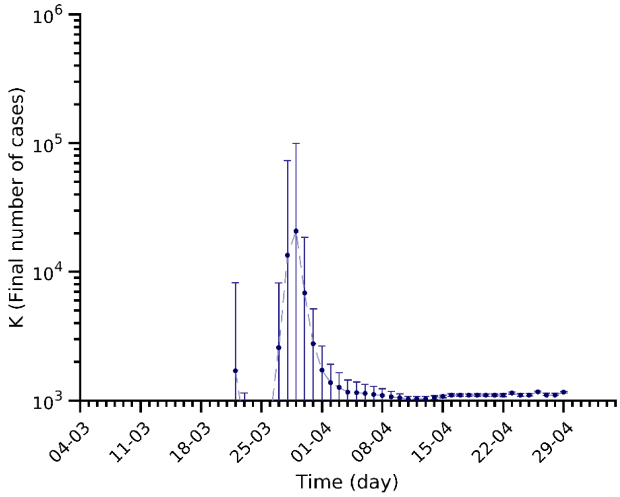


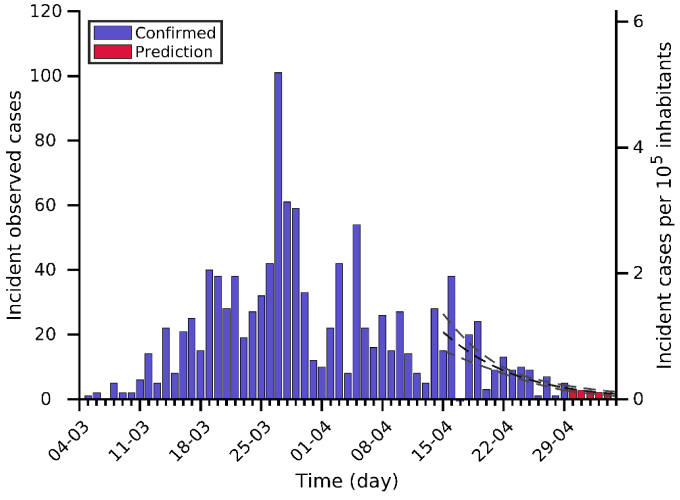
Calabria 29-04-2020. Population: 1.9M. Current cumulated incidence: 57/10^5

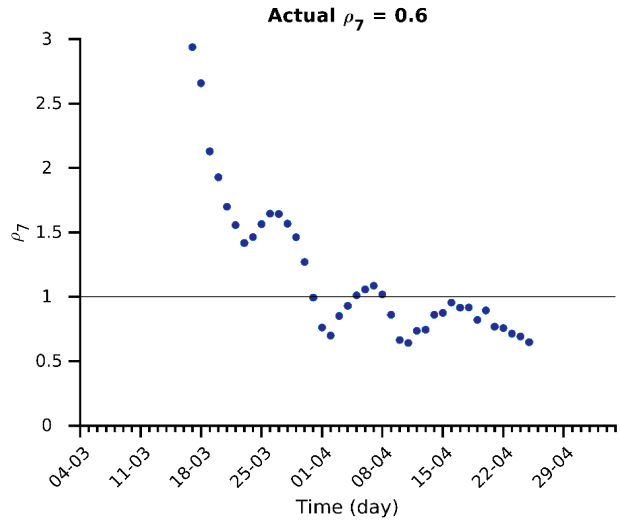


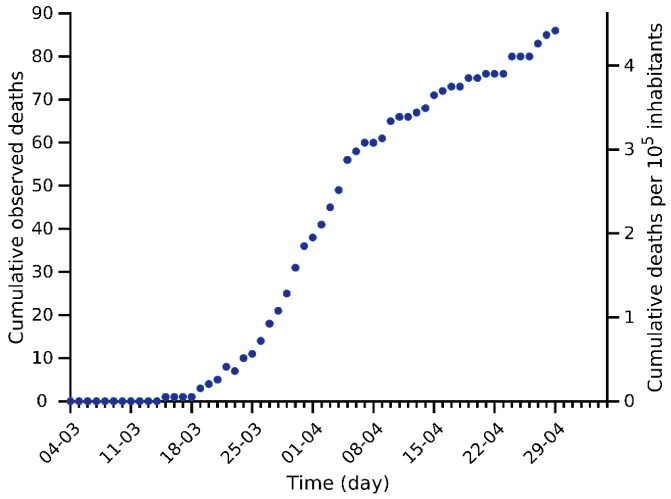


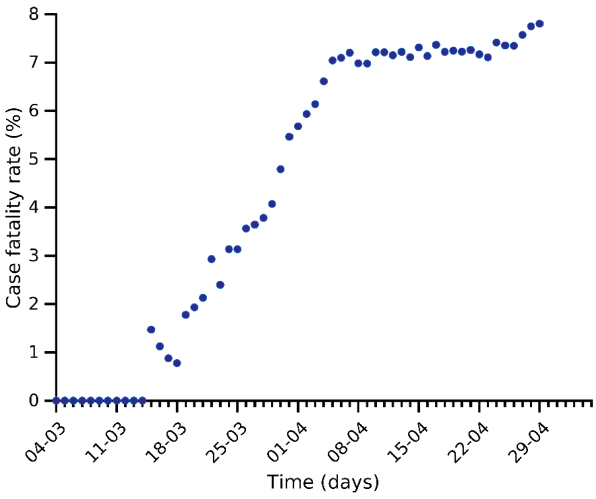




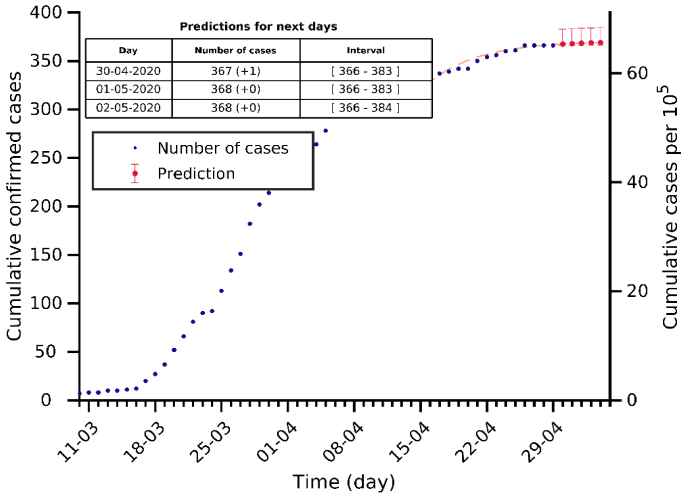


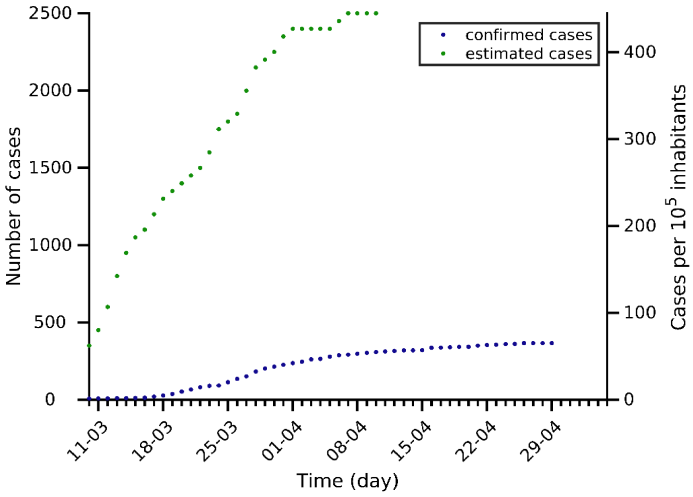


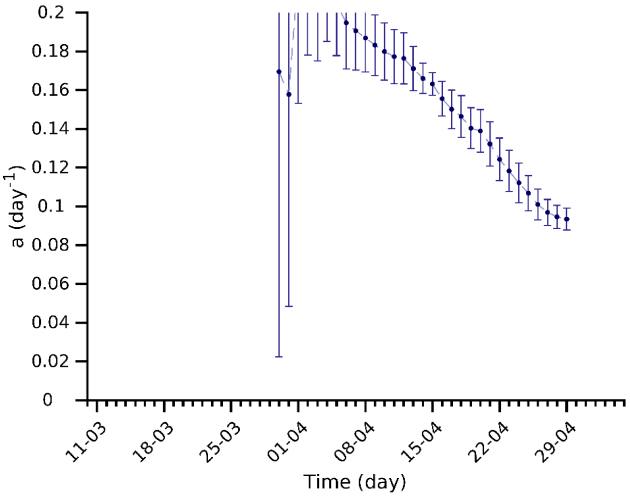


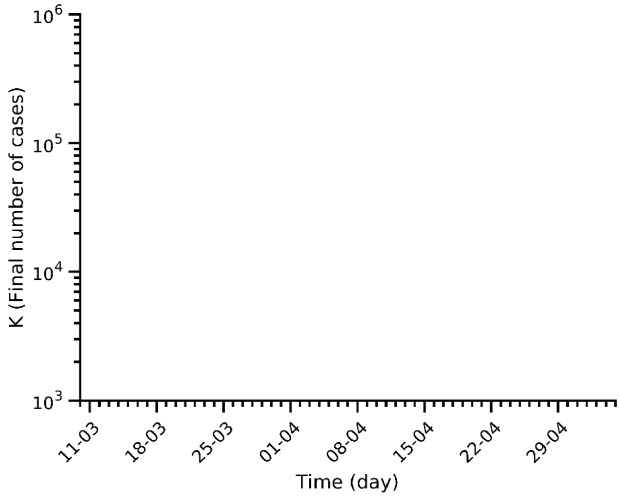


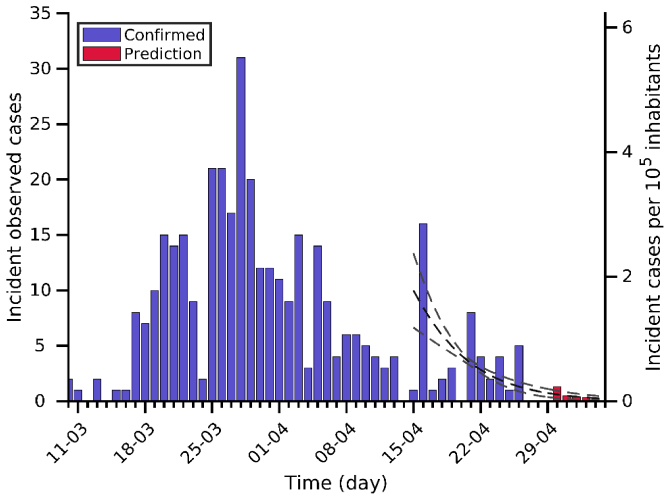
Basilicata 29-04-2020. Population: 0.6M. Current cumulated incidence: 65/10⁵

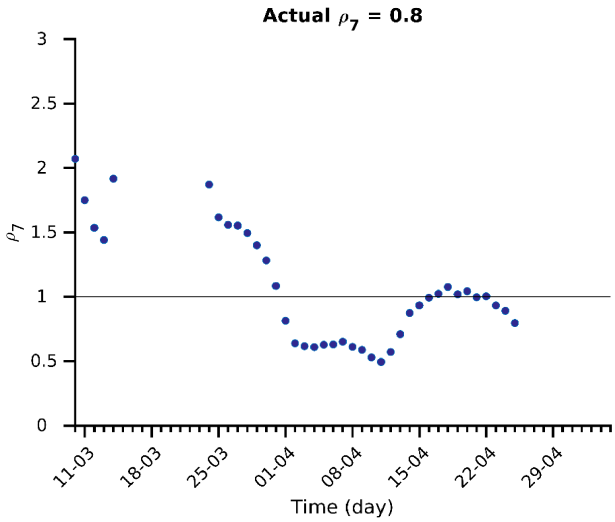


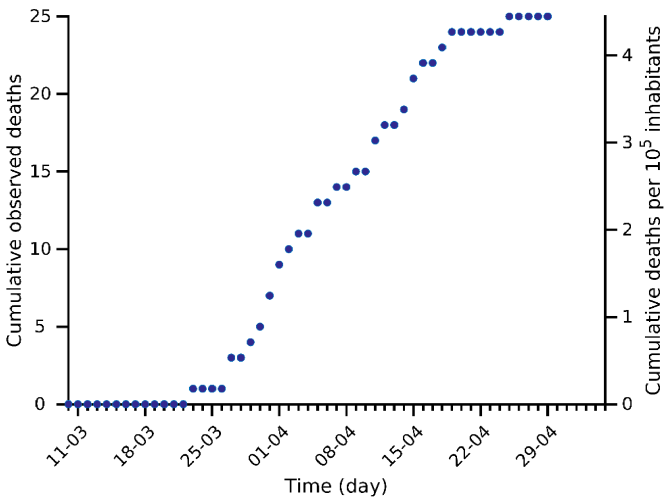


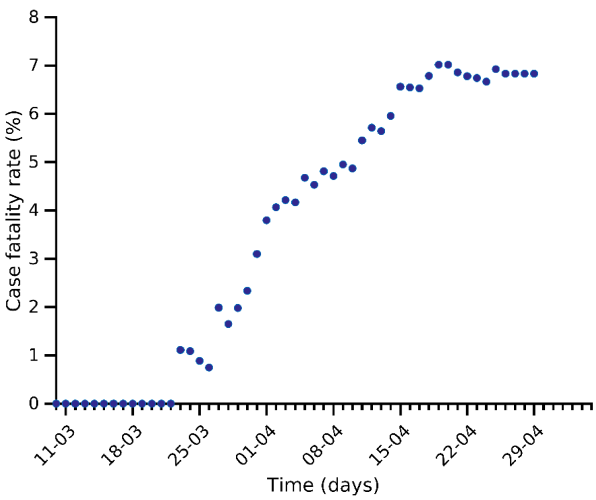




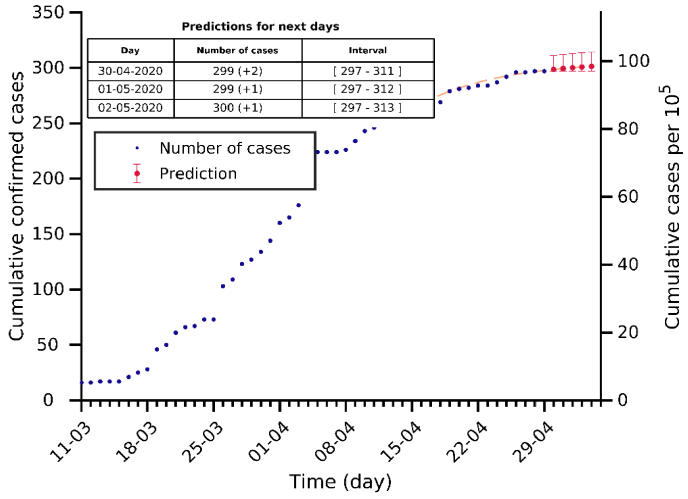


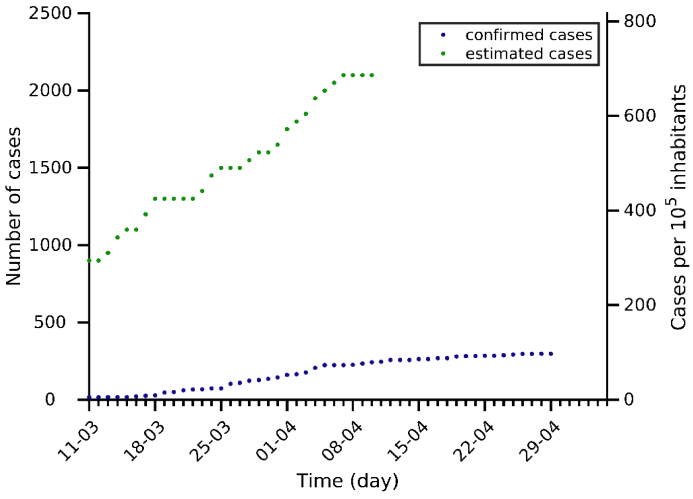


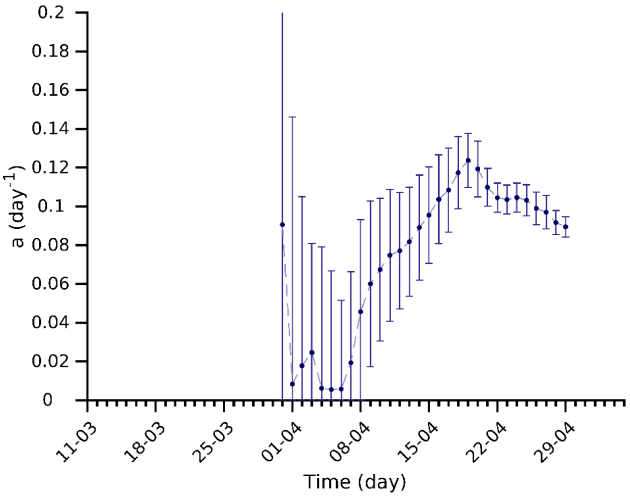


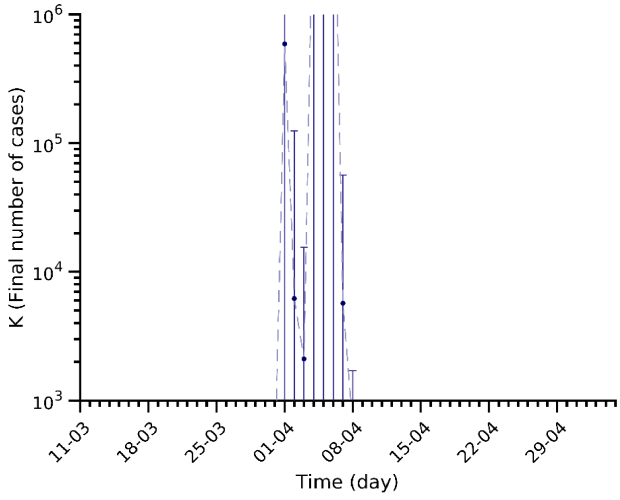


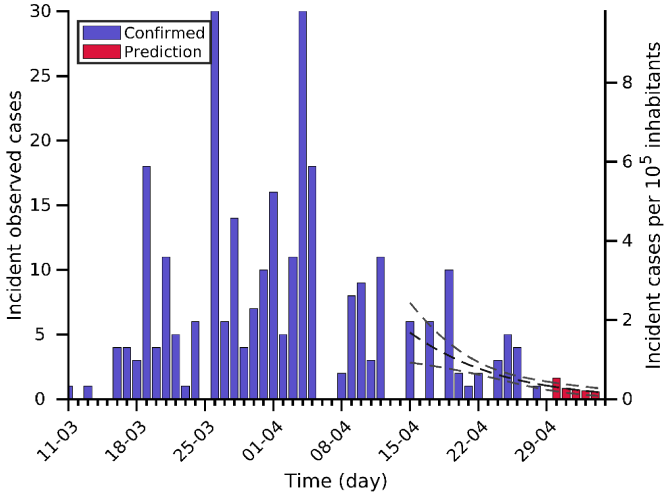
Molise 29-04-2020. Population: 0.3M. Current cumulated incidence: 97/10⁵

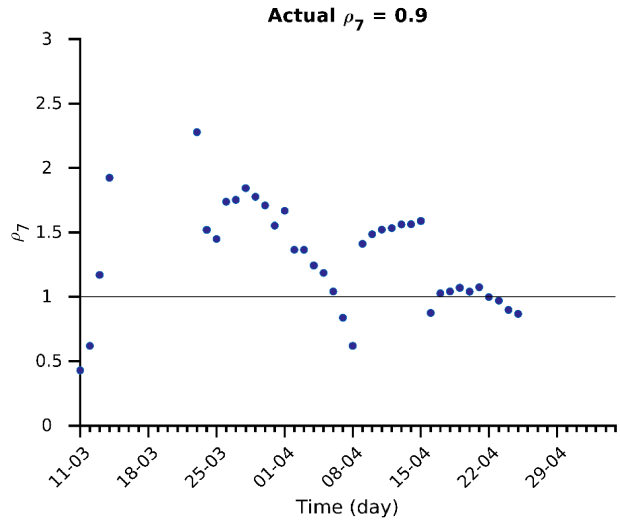


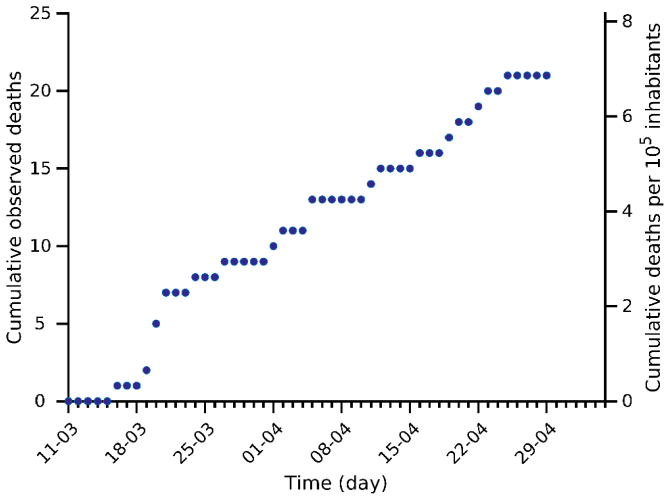


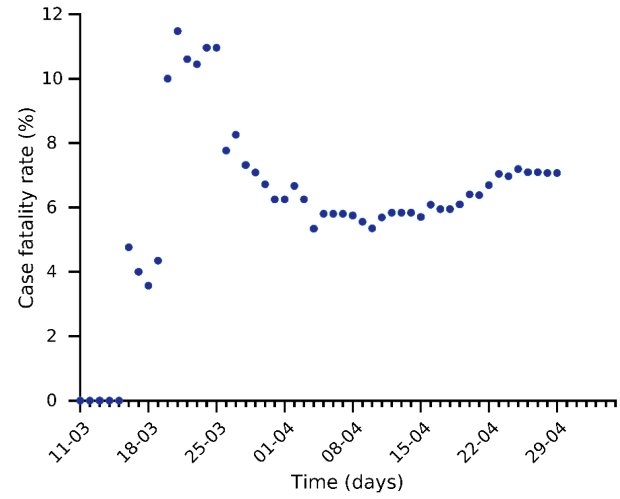












Methods

Methods

(1) Data source

Data are daily obtained from World Health Organization (WHO) surveillance reports[1], from European Centre for Disease Prevention and Control (ECDC)[2] and from Ministerio de Sanidad[3]. These reports are converted into text files that can be processed for subsequent analysis. Daily data comprise, among others: total confirmed cases, total confirmed new cases, total deaths, total new deaths. It must be considered that the report is always providing data from previous day. In the document we use the date at which the datapoint is assumed to belong, i.e., report from 15/03/2020 is giving data from 14/03/2020, the latter being used in the subsequent analysis.

(2) Data processing and plotting

Data are initially processed with Matlab in order to update timeseries, i.e., last datapoints are added to historical sequences. These timeseries are plotted for EU individual countries and for the UE as a whole:

- ✓ Number of cumulated confirmed cases, in blue dots
- ✓ Number of reported new cases
- ✓ Number of cumulated deaths

Then, two indicators are calculated and plotted, too:

- ✓ Number of cumulated deaths divided by the number of cumulated confirmed cases, and reported as a percentage; it is an indirect indicator of the diagnostic level.
- ✓ ρ: this variable is related with the reproduction number, i.e., with the number of new infections caused by a single case. It is evaluated as follows for the day before last report (*t-1*):

$$\rho(t-1) = \frac{N_{new}(t) + N_{new}(t-1) + N_{new}(t-2)}{N_{new}(t-5) + N_{new}(t-6) + N_{new}(t-7)}$$

where $N_{new}(t)$ is the number of new confirmed cases at day t.

(3) Classification of countries according to their status in the epidemic cycle

The evolution of confirmed cases shows a biphasic behaviour:

(I) an initial period where most of the cases are imported;
(II) a subsequent period where most of new cases occur because of local transmission.

Once in the stage II, mathematical models can be used to track evolutions and predict tendencies. Focusing on countries that are on stage II, we classify them in three groups:

- Group A: countries that have reported more than 100 cumulated cases for 10 consecutive days or more;
- Group B: countries that have reported more than 100 cumulated cases for 7 to 9 consecutive days;
- Group C: countries that have reported more than 100 cumulated cases for 4 to 6 days.

[1] https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports
[2] https://www.ecdc.europa.eu/en/geographical-distribution-2019-ncov-cases
[3] https://www.mscbs.gob.es/profesionales/saludPublica/ccayes/alertasActual/nCov-China/situacionActual.htm https://github.com/datadista/datasets/tree/master/COVID%2019 , https://covid19.isciii.es/

(4) Fitting a mathematical model to data

Previous studies have shown that Gompertz model[4] correctly describes the Covid-19 epidemic in all analysed countries. It is an empirical model that starts with an exponential growth but that gradually decreases its specific growth rate. Therefore, it is adequate for describing an epidemic that is characterized by an initial exponential growth but a progressive decrease in spreading velocity provided that appropriate control measures are applied.

Gompertz model is described by the equation:

$$N(t) = K\, e^{-ln\left(\frac{K}{N_0}\right)\cdot e^{-a\cdot(t-t_0)}}$$

where *N(t)* is the cumulated number of confirmed cases at *t* (in days), and N_0 is the number of cumulated cases the day at day t_0. The model has two parameters:

- ✓ *a* is the velocity at which specific spreading rate is slowing down;
- ✓ *K* is the expected final number of cumulated cases at the end of the epidemic.

This model is fitted to reported cumulated cases of the UE and of countries in stage II that accomplish two criteria: 4 or more consecutive days with more than 100 cumulated cases, and at least one datapoint over 200 cases. Day t_0 is chosen as that one at which *N(t)* overpasses 100 cases. If more than 15 datapoints that accomplish the stated criteria are available, only the last 15 points are used. The fitting is done using Matlab's Curve Fitting package with Nonlinear Least Squares method, which also provides confidence intervals of fitted parameters (*a* and *K*) and the R^2 of the fitting. At the initial stages the dynamics is exponential and *K* cannot be correctly evaluated. In fact, at this stage the most relevant parameter is *a*. Fitted curves are incorporated to plots of cumulative reported cases with a dashed line. Once a new fitting is done, two plots are added to the country report:

- ✓ Evolution of fitted *a* with its error bars, i.e., values obtained on the fitting each day that the analysis has been carried out;
- ✓ Evolution of fitted *K* with its error bars, i.e., values obtained on the fitting each day that the analysis has been carried out; if lower error bar indicates a value that is lower than current number of cases, the error bar is truncated.

These plots illustrate the increase in fittings' confidence, as fitted values progressively stabilize around a certain value and error bars get smaller when the number of datapoints increases. In fact, in the case of countries, they are discarded and set as "Not enough data" if $a>0.2\ day^{-1}$, if $K>10^6$ or if the error in K overpasses 10^6.

It is worth to mention that the simplicity of this model and the lack of previous assumptions about the Covid-19 behaviour make it appropriate for universal use, i.e., it can be fitted to any country independently of its socioeconomic context and control strategy. Then, the model is capable of quantifying the observed dynamics in an objective and standard manner and predicting short-term tendencies.

(5) Using the model for predicting short-term tendencies

The model is finally used for a short-term prediction of the evolution of the cumulated number of cases. The predictions increase their reliability with the number of datapoints used in the fitting. Therefore, we consider three levels of prediction, depending on the country:

[4] Madden LV. Quantification of disease progression. Protection Ecology 1980; **2**: 159-176.

- Group A: prediction of expected cumulated cases for the following 3-5 days[5];
- Group B: prediction of expected cumulated cases for the following 2 days;
- Group C: prediction of expected cumulated cases for the following day.

The confidence interval of predictions is assessed with the Matlab function `predint`, with a 99% confidence level. These predictions are shown in the plots as red dots with corresponding error bars, and also gathered in the attached table. For series longer than 9 timepoints, last 3 points are weighted in the fitting so that changes in tendencies are well captured by the model.

(6) Estimating non-diagnosed cases

Lethality of Covid-19 has been estimated at around 1 % for Republic of Korea and the Diamond Princess cruise. Besides, median duration of viral shedding after Covid-19 onset has been estimated at 18.5 days for non-survivors[6] in a retrospective study in Wuhan. These data allow for an estimation of total number of cases, considering that the number of deaths at certain moment should be about 1 % of total cases 18.5 days before. This is valid for estimating cases of countries at stage II, since in stage I the deaths would be mostly due to the incidence at the country from which they were imported. We establish a threshold of 50 reported cases before starting this estimation.

Reported deaths are passed through a moving average filter of 5 points in order to smooth tendencies. Then, the corresponding number of cases is found assuming the 1 % lethality. Finally, these cases are distributed between 18 and 19 days before each one.

[5] At this moment we are testing predictions at 4 days for countries with more than 100 cumulated cases for 13-15 consecutive days, and 5 days for 16 or more days.

[6] Zhou et al., 2020. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. The Lancet; March 9, doi: 10.1016/S0140-6736(20)30566-3